View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Boston University Institutional Repository (OpenBU)

Boston University

OpenBU **http://open.bu.edu**

Questrom School of Business BU Open Access Articles

2020-03

Internet-of-things enabled supply chain planning and coordination with big data services: cert...

This work was made openly accessible by BU Faculty. Please share how this access benefits you. Your story matters.

Version	Published version
Citation (published version):	Longfei He, Mei Xue, Bin Gu. 2020. "Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications." Journal of Management Science and Engineering, Volume 5, Issue 1, pp. 1 - 22. https://doi.org/10.1016/j.jmse.2020.03.002

https://hdl.handle.net/2144/42887

Boston University

Boston University Libraries
OpenBU

Journal of Management Science and Engineering 5 (2020) 1–22

Contents lists available at ScienceDirect

Journal of Management Science and Engineering

journal homepage: www.keaipublishing.com/en/journals/journal-of-management-science-and-engineering/

Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications

Longfei He [a,*], Mei Xue [b], Bin Gu [c]

[a] College of Management and Economics, Tianjin University, Tianjin, 300072, China
[b] Carroll School of Management, Boston College, Boston, MA, 02467, USA
[c] Questrom School of Business, Boston University, Boston, MA, 02215, USA

ARTICLE INFO

Article history:
Available online 29 March 2020

Keywords:
Internet of things
Supply chains
Intelligent interconnections
Resources allocation
Big data analytics
Coordination and optimization

ABSTRACT

Recent advances in information technology have led to profound changes in global manufacturing. This study focuses on the theoretical and practical challenges and opportunities arising from the Internet of Things (IoT) as it enables new ways of supply-chain operations partially based on big-data analytics and changes in the nature of industries. We intend to reveal the acting principle of the IoT and its implications for big-data analytics on the supply chain operational performance, particularly with regard to dynamics of operational coordination and optimization for supply chains by leveraging big data obtained from smart connected products (SCPs), and the governance mechanism of big-data sharing. Building on literature closely related to our focal topic, we analyze and deduce the substantial influence of disruptive technologies and emerging business models including the IoT, big data analytics and SCPs on many aspects of supply chains, such as consumers value judgment, products development, resources allocation, operations optimization, revenue management and network governance. Furthermore, we propose several research directions and corresponding research schemes in the new situations. This study aims to promote future researches in the field of big data-driven supply chain management with the IoT, help firms improve data-driven operational decisions, and provide government a reference to advance and regulate the development of the IoT and big data industry.

© 2020 China Science Publishing & Media Ltd. Publishing Services by Elsevier B.V. on behalf of KeAi Communications Co. Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

The widespread adoption of the Internet of Things (IoT) is triggering profound changes in global manufacturing and business competition (Porter & Heppelmann, 2014, 2015). Accordingly, MIIT (2015) states that "the deep integration of next-generation information technology and manufacturing is activating far-reaching industrial changes, forming new production modes, industrial forms, business models and economic growth points." Actually, a number of countries around the world have developed plans of developing the IoT and Industry 4.0 that are regarded as key technologies to affect national competitiveness (Hou & Zhang, 2014; Li, 2010; MIIT, 2011; MIIT, 2015; Ni, 2011; Xi, 2014). Given the emphasis these countries

* Corresponding author.
E-mail address: helf@tju.edu.cn (L. He).

https://doi.org/10.1016/j.jmse.2020.03.002
2096-2320/© 2020 China Science Publishing & Media Ltd. Publishing Services by Elsevier B.V. on behalf of KeAi Communications Co. Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

attach to the changes incurred by emerging technology, the IoT has become a part of the manufacturing strategies of many countries. It will become an important driving force for emerging economies to realize economic transformation and industrial upgrade, and to accelerate the high-level industrialization and information integration.

MIT Auto-ID Labs first introduced the concept of the IoT in 1999, which advocates connecting computers and internet with various things to form a larger network through ubiquitous sensors. Combining the IoT definition in the existing literature (Ashton, 2009; Atzori, Iera, & Morabito, 2010; Gubbi, Buyya, Marusic, & Palaniswami, 2013; ITU, 2005; Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012), we can define the IoT as the collection and transformation of various information of things via intelligent sensing devices and internet respectively to a designated processing center for realizing automatic information interactions among things and people.

The extensive use of IoT tremendously facilitates the generation of big data, and the effective use of big data will greatly promote the effectiveness and efficacy of operations management with IoT (Ashton, 2009; Lavalle, Lesser, Shockley, Hopkins, & Kruschwitz, 2011; Wu, 2013a). The information interaction and transformation arising from IoT-enabled interconnection generate a large amount of high-speed, varying and unstructured big data. As a disruptive technology, big data analytics finds new rules and creates value through the integration analysis and deep mining of massive real-world data, and then seamlessly link the physical world to the digital world. (Frankel & Reid, 2008; Hilbert & López, 2011; Lavalle et al., 2011; Lynch, 2008; Wu, 2013b).

In view of the IoT's significance, academia has paid close attention to it. As pointed out by Sendler et al. (2014), Porter and Heppelmann (2014) and Tien (2015), the IoT enables the intelligent manufacturing that is characterized by high digitalized, networking and self-organizing production and based on cyber physical systems. It will have a profound and significant impact on the global manufacturing industry, which may eventually lead to a new industrial revolution.

Moreover, representative enterprises like Gartner and Software AG argue that "the IoT will radically boost industrial innovation and affect business operations". The consensus of the industry suggests that the IoT and IoT-enabled big data analytics will have a huge impact on many aspects of resources acquisition and integration, production operations, transactions, and products, which can greatly improve the efficiency of commodity production and distribution, and dramatically change the production and consumption patterns of the socio-economic system over the world. The IoT technology has been widely used in manufacturing (e.g. Siemens, Gree and Midea), intelligent transportation (Shanghai Automotive, Huawei and FutureMove Auto, Didi and Uber), logistics and distribution, clothing industry and healthcare (Iovweek, 2015; Sina, 2014; Xu, 2014). Among those diverse IoT-enabled applications, the common feature is that they all provide the so-called smart connected products (SCPs), which means intelligently interconnected products or services via the IoT. For more information about the definition of SCPs, one can refer to Porter and Heppelmann (2014).

The distinctive feature of the IoT is the things-to-things(T2T) connection, which is embodied as SCPs in the consumption and the interconnection of devices in the production, respectively. In the underlying IoT context, information on the resources, capacities, and production status is transmitted in real time, from which big data becomes a new substantial production factor for supply chain operations. It is therefore natural and necessary to discuss several key big-data driven issues in supply chains since big-data analytics can have a significant impact on the performance of IoT-enabled supply chain as well as the efficacy of the IoT.

SCPs are fundamentally different from traditional products, because they are composed of three kinds of core components: physical components, intelligent components and connecting components. Intelligent components strengthen the value and function of physical components, which is enhanced further by connecting components and creating new functions and values existed out of physical components, thus forming a virtuous circle of value promotion (Porter & Heppelmann, 2014; Tien, 2012, 2015). In the IoT environment, information technology and data itself become an integral part of the product. The sensors, processors, software and connecting parts embedded in the product, real-time dynamic data transmission and synchronous data storage analysis and application running in the product cloud greatly improve the product functionality and performance. Therefore, compared with traditional products, SCPs can provide new functions, higher reliability, higher product utilization, and cross-border or even beyond the boundaries of traditional products. In many SCPs, software replaces physical accessories or makes a single physical device run under different conditions. The connection between products can produce two functions: to enable the information exchanges among products, manufacturers, operating systems and users; and to create new digital functions independently of physical products (Porter & Heppelmann, 2014, 2015; Tien, 2012, 2015).

The composition and characteristics of SCPs have changed the nature of industrial structure and competition, making enterprises face many new opportunities and challenges of competition, and will reshape the industrial boundary (Porter & Heppelmann, 2014). In addition, from the perspective of the supply side, the IoT architecture and its derived big data analytics greatly improve the economic production efficiency of new products. The production of such products requires changes to product design, manufacturing, logistics, marketing and after-sales service, and even spawns new production taches such as product big data analytics to reshape the value chain again. This will trigger a new value chain-based productivity improvement. The scope and way of resource acquisition will also change substantially. Enterprises can allocate resources more efficiently and on a larger scale. This will promote a large degree of change in production organization mode.

More importantly, how big data analytics, related to resources, capabilities and status information of products and production facilities in the IoT environment, can effectively promote the efficiency in supply chain operations; and how a firm can formulate an effective supply chain big-data sharing governance mechanism present new critical but challenging issues emerging in the IoT-underlying supply chains.

In summary, the IoT technology has radically changed the environment in which the supply chains operate. Real-time massive data and information are spread faster in the supply chain, and the efficiency of resource discovery and utilization will also be greatly improved. However, the visualization level of supply chain resources and the utilization of big data will still depend on companies' own decisions and their decision interactions with other supply chain partners. However, the IoT technology has changed the technical foundation for the construction and operation of economic systems, which then brings important and essential changes in market demand, production organization and supply chain operations. This IoT-enabled new ecosystem brings about emerging management issues. For example, how the emergence and popularization of the IoT-enabled SCPs influence consumer value proposition and consumer behavior? How does this affect corporate products design? IoT and SCPs have changed the way of value creation and formed new operations models, which will pose new challenges to the supply chain structure, network governance and the design of corresponding coordination mechanisms. In addition, how can enterprises optimally acquire resource and capacities in the IoT-enabled supply chains, and how to determine new product dynamic pricing strategies for SCPs under the aforesaid values entanglement. These emerging questions that arise in the new management context of the IoT cannot be answered by prior researches. This study intends to proceed from the in-depth analysis of the essential characteristics of IoT enabled supply chain operations driven by big data analytics, and then, on the basis of a review to the related cutting-edge researches, addresses new management issues emerging in the supply chain operation in this context with valuable research directions in the future.

The reminder of this paper is organized as follows. We provide a brief summary to the relevant literature in Section 2. Section 3 accommodates the research framework playing a role of the research design for this study. The focal Sections 4, 5, 6 and 7 are devoted to elaborating respectivly core research directions with implementation schemes suggested, according to the framework in Section 3. Section 8 concludes the paper.

2. Related literature

Although the IoT-enabled big data driven supply chain operations has only recently formally received close attention from the industry, the research on the combination of IoT-related technological components (such as Radio frequency identification (RFID), cloud computing, etc.) and supply chain management has appeared earlier. These research topics include RFID technology and supply chain management, cloud manufacturing and cloud computing, big data and operations management, and so on.

Due to the close relationship between RFID and the IoT, we can't bypass RFID to talk about the IoT. However, note that the functional role and effect of the RFID and cloud computing technologies are fundamentally different from that of IoT-based intelligent interconnection as the RFID and cloud computing are only functionally technological components (hardware or software) of IoT (Presser & Gluhak, 2009). The focus of these studies is distinct from the emerging issues of IoT-enabled big-data driven supply chain operations that this paper just focuses on. In order to highlight the theme and content of the present research, this section only reviews the research results that are representative of the above fields and are most relevant to this research.

2.1. RFID-enabled supply chain management

RFID is a kind of wireless communication technology, which can identify specific targets and read and write relevant data through radio signals, without establishing mechanical or optical contact between the identification system and specific targets. (Dutta, Lee, & Whang, 2007; Ranky, 2012). As a basic component of IoT, RFID has been applied extensively, while only recently has IoT developed rapidly due to in-depth information and communications technology (ICT) advancement after a long-time silence since its emergence.

RFID's technical feasibility and convenience reflected in the definition and working principle, especially the real-time information transmission between multiple targets, makes it a great success in industry and commerce. (García, Chang, Abarca, & Oh, 2007; Gaukler, 2005; McFarlane, Sarma, Chirn, Wong, & Ashton, 2003). This provides the impetus and case materials for the later large-scale academic research. P & G and Wal-Mart may be the first companies that achieved significant benefits from the application of RFID technology, such as 70% reduction in inventory, 3% improvement in service level, and significant reduction in supply chain costs (Bottani & Rizzi, 2008; Thonemann, 2002). The successful application of RFID prompted academia to investigate its impact on enterprises and supply chain operations.

Some scholars directly observe the role of RFID in enterprises and supply chains from the angle of business cases. Their studies show that companies usually use pilot projects to test RFID application in simple situation before promoting it to the entire enterprise. For example, Alexander et al. (2002) report firms' adoption obstacle of RFID in retail value chain, and describe the impact of Auto-ID systems on specific operational issues. Bitkom-RFID-Project-Group (2005) uses case study to show that RFID technology reduces transportation-related products loss by more than 11%, increases products availability at the retail-end by 14%, and decreases distribution cost by 11%. Similar studies reflecting RFID's values include Kambil and Brooks (2002), Chappell et al. (2002), Chappell et al. (2003), Tellkamp (2003), Lee, Cheng, and Leung (2004), Tellkamp (2006), Baysan and Ustundag (2013) and Bilal and Martin (2014). There are other case studies investigating the role of RFID in supply chain operation practices such as inventory management, logistics and transportation, assembly manufacturing, asset tracking and item positioning (Banks, Hanny, Pachano, & Thompson, 2007; Baysan & Ustundag, 2013; Gaukler & Seifert, 2007; Hedgepeth, 2007; Li, Visich, Khumawala, & Zhang, 2006).

Theoretical research on RFID-embedded supply chain management focuses on supply chain operations in three aspects including inaccurate inventory (Atali, Lee, & Ozer, 2009; Fan, Chang, Gu, Yi, & Deng, 2014; Fleisch & Tellkamp, 2005; Kang & Gershwin, 2005), bullwhip effect (Joshi, 2000; Lee, Cheng, & Leung, 2009) and replenishment policy (Kök & Shang, 2007; Lee et al., 2009). Furthermore, Dutta et al. (2007) comprehensively expounded the three dimensions of value added and the areas to be explored in the future from the perspective of technology, value and incentives (Dutta & Whang, 2007). Existing literature also presents different characteristics in the research methods used for RFID value recognition and excavation. For example, different from the previous literature that describing the impact of RFID on supply chain management qualitatively, Lee and Özer (2007) first proposed that the value of RFID to supply chain management should be precisely modeled and quantified through mathematical models and quantitative methods. Along the same line, Rekik, Sahin, and Dallery (2008) analyzed the role of RFID in reducing the misplacement rate of goods along this line. Brown, Inman, and Calloway (2001), Leung, Cheng, Lee, and Hennessy (2007), and Amini, Otondo, Janz, and Pitts (2007) use simulation analysis methods to explore the impact of RFID on inventory check, while other studies exploit other methods like case studies, empirical and experiments (such as Lefebvre, Lefebvre, Bendavid, Wamba, & Boeck, 2006; Whitaker, Mithas, & Krishnan, 2009; Fosso Wamba, Lefebvre, & Lefebvre, (2007); Barratt & Choi, 2007; DeHoratius & Raman, 2008; Bottani & Rizzi, 2008). In the following is a brief review to the literature on three typical aspects of RFID-enhanced inventory management, i.e. inventory inaccuracy, bullwhip effect and replenishment strategy.

An increasing body of literature has focused on the impact of RFID on inventory inaccuracies. The problem inventory inaccuracy has received extensive concerns since it was first proposed by Iglehart and Morey (1972), and studies on using RFID to reduce inventory inaccuracy have become prevalent in the past decade. Although firms often pursue the automatic inventory management by constructing information system, there is often a mismatch between the inventory level in the information system and the actual inventory level, which will have a profound impact on the performance of the enterprise (Kang & Gershwin, 2005; Lee, Cheng, & Leung, 2009). Some literature has proposed that RFID can significantly decrease occurrence probability of inventory inaccuracy caused by transaction errors, inventory losses, inventory misplacement, and supply errors through real-time data capture and communication, as addressed in Zipkin (2006), Fleisch and Tellkamp (2005), Lee, Cheng, and Leung (2009), Gaukler (2005), Sahin, Buzacott, and Dallery (2008), Rekik, Sahin, and Dallery (2009), Rekik (2011), Xu (2012), Dai and Tseng (2012), Fan, Chang, Gu, Yi, and Deng (2014), Piramuthu, Wochner, and Grunow (2014), Fan, Tao, Deng, and Li (2015).

Exploiting RFID to solve the bullwhip effect in the supply chain is another research focus in the literature. Since Forrester (1958) first proposed the bullwhip effect, scholars have tried to explain the cause of the bullwhip effect. The most representative are Lee, Padmanabhan, and Whang (2004), Geary et al. (2006), Wang, Liu, and Wang (2008). The consensus is that the bullwhip effect is incurred by demand fluctuations, compounded by information lag and inaccuracy and human factors. Meanwhile, other scholars provide various methods to eliminate the bullwhip effect. Chen et al. (2000) uncover how the bullwhip effect influences supply-chain corporate behavior and operational performance. Subsequently, Holweg et al. (2005) pointed out that the bullwhip effect can be mitigated through supply chain collaboration and information visibility. The representative literature exploring the impact of RFID on the bullwhip effect includes Bottani and Rizzi (2008), Wang, Liu, and Wang, (2008), Zhou (2009), Gaukler (2011), Zhou and Piramuthu (2013), Musa, Gunasekaran, and Yusuf (2014), and Nooraie and Parast (2015). They argue that the RFID-enabled supply chains can achieve information sharing, reduce information distortion, more accurate prediction, real-time information transmission, and, therefore, RFID can play a role in weakening bullwhip effect and improving supply chain performance.

In the existing literature, studying how RFID affects firms' replenishment behavior and strategy is another major research focus. The replenishment strategy mainly determines the replenishing frequency and quantity to maximize customer satisfaction. Based on the traditional inventory model, a variety of literature applies RFID technology to different operational replenishing scenarios and compare the optimal replenishment strategy for the RFID-enabled firms with that of non-RFID firms, such as Kök and Shang (2007), Lee, Cheng, and Leung (2004), Kang and Gershwin (2005), Condea, Thiesse, and Fleisch (2012), Mersereau (2013), Chen (2014) and Thiesse and Buckel (2015).

The representative literature on the impact of RFID on supply chain management is summarized in Table 1 in accordance with research types, concerns and other categories, which also gives the common scientific methods of these studies.

From the above literature review, we can see that RFID technology promotes the performance of supply chains through its technical characteristics (unique identification of products, real-time communication and information sharing), and its effect can be embodied in different forms of supply chain, such as warehousing, transportation, production planning, order management, inventory and asset management. RFID can improve the traceability and visibility of products in the entire supply chain, and bring improved inventory flow and more accurate information. However, as a basic technological component of the IoT, RFID can only serve the simple function of data collection and unidirectional information transmission, unable to realize the IoT-enabled scenarios and functions of T2T, Machine-to-Machine interconnection and Human-to-Machine interaction and bi-directional communication.

2.2. Cloud manufacturing and cloud computing

Cloud manufacturing and cloud computing are new ingredients of the emerging manufacturing modes and service-oriented computing modes have evolved rapidly in recent years. They are related to the IoT-enabled supply chain operations mentioned in this study. In this section, we will briefly review the research in this area.

Table 1
Classification of typical literature of RFID-enabled supply chain management.

Focus	Main concerns	Typical literature
Inventory inaccuracy	Exploring the application of RFID to eliminate transaction negligence, inventory loss, inventory misplacement, and supply fault	Amini, Otondo, Janz, and Pitts, (2007); Biswal, Jenamani, and Kumar (2018); Çakıcı, Ö. E., and Ö. E. (2011); Cannella, Framinana, Bruccoleri, Barbosa-Povoa, and Relvas (2015); Chen et al. (2014); Cui, Deng, Liu, Zhang, and Xu, (2017); Dai, Tan, and Zhou, (2018); Dai and Tseng, (2012); Dan, Mao, and Xu, (2012); DeHoratius and Raman (2008); Fan, Tao, Deng, and Li (2015); Fan, Chang, Gu, Yi, and Deng (2014); Fleisch and Tellkamp (2005); Gaukler (2011); Hardgrave, Aloysius, and Goyal (2013); Heese (2007); Lee, Cheng, and Leung (2009); Leung, Cheng, Lee, and Hennessy (2007); Li and Wang (2018); Rekik (2011); Rekik, Sahin, and Dallery (2008, 2009); Sahin, Buzacott, and Dallery (2008); Tao, Fan, Lai, and Li (2017); Tao, Fan, Wang, and Lai (2019); Tao, Lai, Wang, and Fan (2020); Wang, Fang, Chen, and Li (2016); Wang, Hu, Chang, and Ding (2018); Zhang, Fan, and Liu (2017); Zhang, Hu, Fan, and Yang (2012); Zhang, Li, and Fan (2018); Zhang and Wang (2019); Zipkin (2006)
Bullwhip effect	Using RFID to realize information sharing and reduce information distortion in supply chain to weaken bullwhip effect	Bottani and Rizzi (2008); Cannella, Dominguez, and Framinan (2017); Dai, Li, Yan, and Zhou (2016); Delen, Hardgrave, and Sharda (2007); Hardgrave, Aloysius, and Goyal (2013); Musa, Gunasekaran, and Yusuf (2014); Nooraie and Parast (2015); Thiesse and Buckel (2015); Wang, Liu, and Wang (2008); Zhang, Li, and Fan (2018); Zhou, (2009); Zhou and Piramuthu (2013)
Replenishment policy	How RFID changes the replenishment strategy of enterprises	Biswal, Jenamani, and Kumar (2020); Chen (2014); Condea, Thiesse, and Fleisch (2012); Cui et al. (2020); Cui, Deng, Wang, Zhang, and Xu (2018); Kang and Gershwin (2005); Kök and Shang (2007); Li and Wang (2018); Li, Wang, and Chan (2016); Mersereau (2013); Metzger, Thiesse, Gershwin, and Fleisch (2013); Park, Hong, and Lee (2015); Thiesse and Buckel (2015); Zadeh, Sharda, and Kasiri (2016); Zhang and Yang (2019)

Li, Ji, Qi, Xin, and Tang (2010) pioneer in defining cloud manufacturing as a new networked manufacturing model, which uses the network and cloud manufacturing service platform to organize online manufacturing resources (manufacturing cloud) according to market needs, and platform users provide on-demand manufacturing services. Cloud manufacturing technology integrates the existing networked manufacturing and service technologies with cloud computing, cloud security, high-performance computing, IoT and other technologies to realize the unified and centralized intelligent management and operation on various manufacturing resources,[1] providing various types of manufacturing activities services that are readily available, on-demand, safe, reliable, and high-quality and cheap for the entire life cycle of manufacturing (Li, et al., 2010).

The philosophy of cloud computing[2] is to build computer storage and computing service centers by professional computer and network companies (i.e., third-party service providers), and virtualize resources into "cloud" to centrally store and provide services to users (Chen & Zheng, 2009). Cloud computing is an extension of virtualization and grid computing, but it brings a shift in service models, which makes computing resources a professional service and provides it through information technology (Li et al., 2010). Many well-known companies like Google, IBM, Amazon, Yahoo, etc. have invested resources in launching their cloud computing projects. Different cloud computing application forms have emerged, typically software as a service, utility computing, network service, and platform as a service, management service provider, business service platform, Internet integration, cloud simulation platform and so on.

Cloud manufacturing has both theoretical and practical significance, which is developed on the basis of existing networked manufacturing modes (e.g. application service providers, manufacturing grids, and agile manufacturing). It is to overcome the latter's existing service models, manufacturing resource sharing, distribution technologies and security. The emergence of cloud computing just provides a good technical foundation for the implementation of cloud manufacturing. Following Li et al. (2010), a number of studies spring out, which mostly focus on two research issues: (1) Service model design and innovation of cloud manufacturing, such as Fan and Xiao (2011), He, Song, Wang, and Xu (2011), Huang, Zhong, Long, and Zhang (2011), Ren, Lin, Tao, and Luo (2011), Yin et al.(2011), Zhang, Luo, Fan, Tao, and Ren (2011), Xu (2012), Li, Tan, Li, and Chai (2012), Wang, Yang, Zhang, Chen, and Zhao (2012), Yao et al. (2012), Yin, Zhang, and Zhong (2012), Zhan, Cheng, Zhao, Nie, and Xu (2012), Huang et al. (2013), Wu et al. (2013), Guo, Tong, Shao, Wang, and Zheng (2013), Zhang, Luo, et al. (2014), Jin (2014), Ma, Zhu, and Wang (2014), Yao, Lian, Yang, Zhang, and Jin (2014); (2) Technology of resource sharing and allocation in cloud manufacturing, like Li et al. (2010), Zhang et al. (2011), Shen, Qi, and Fan (2011), Yin, Huang, et al. (2011), Li,

[1] Including manufacturing devices, computing systems, software, models, data, knowledge, etc.
[2] IBM. Cloud and IT optimization. Retrieved from http://www-03.ibm.com/software/products/zh/category/cloud-it-optimization.

Zhang, et al. (2012), Li, Wang, et al. (2012), Li, Liu, et al. (2012), Luo, Zhang, Tao, Zhang, and Ren (2012), Wang and Xu (2013), and Zhang, Zhang, et al. (2014).

Cloud manufacturing and cloud computing have certain connections with the IoT. For instance, cloud manufacturing often requires the use of the IoT, and supply chains embedded in the IoT requires cloud-computing technology to realize a cloud platform for resources integration. However, cloud manufacturing is essentially different from the IoT-enabled supply chain operations proposed in this study. Their difference can be understood as follows. The core concepts of "centralized use of decentralized resources" and "decentralized use of centralized resources" (Li et al., 2010) embodied in cloud manufacturing emphasize the optimization of resources allocation, but it scarely takes into account that enterprises are the self-interest decision-makers subject to economic rationality. The consideration of their own interests often leads to the suboptimal allocation results. Furthermore, the changes in corporate behavior and organizational structure caused by the co-creation of products and services in the IoT environment are also not covered by cloud manufacturing. Nevertheless, the micro-behavior of enterprises and the interaction of decision-making among chain agents are exactly the focus of big data-driven supply chain operations in the IoT environment concerned in this study.

2.3. Big data and operations management

The supply chain operations under the IoT environment may generate a large amount of data information, which brings out the value chains of big-data analytics services. In this section, we briefly review existing research on the operational management enabled by big data analytics.

Big data refers to that the amount of data involved is so huge that it cannot be intercepted, managed, processed and organized into human-readable information within a reasonable time (Vance, 2010). As a large-scale, high-speed, changeable and real information asset, it needs new processing methods to promote stronger decision-making capabilities, insight, and optimized processing (Beyer & Laney, 2012; White, 2012).

Since the publication of Bryant, Katz, and Lazowska (2008), the industry and academia have developed a great interest in the application of big data. Many companies have used big data analytics in their own business practices, such as IBM, Wal-Mart, Amazon, Taobao, eBay and China Mobile, etc. In terms of theoretical research, many of the existing big-data related research is conducted at information sciences, focusing on the acquisition, storage, processing, mining and information security of big data, and only some explores the influence of big-data analytics on the production management and business operation decisions from the perspective of management. (Feng, Guo, Zeng, Chen, & Chen, 2013; Lavalle et al., 2011; Schoenherr & Speier-Pero, 2015; Wu & Wang, 2014; Xu, Feng, Guo, Zeng, & Chen, 2014). From the features of data *per se*, problem and management decision-makings in big data driven implementations, Chen et al. (2018) address the paradigm change on research and application of management decision-makings, and gives a groundbreaking panoramic management decision-making framework, which is a factor matrix formed by the combination of three features of big-data problem times four typical research directions. Their research provides a pivotally comprehensive perspective and guidance for future research on big data-driven decision-makings. In this regard, our study is highly related to Wang, Fang, Chen, and Li (2016) in this field, in which they propose the concept of supply chain analytics and its maturity framework by combining the nature of big data analytics and features of logistics and supply chain management, yet their research does not address some concerns of supply chain coordination and optimization issues incurred by big data services, data sharing and chain governance under IoT environment.

Some recent literature has explored the possibility of applying big data analytics to operations and supply chain management. After discussing the advantages, shortcomings and main functions of big data related technologies, Choi, Wallace, and Wang (2018) reveals how diversified operation management sub-fields have applied different big data analytics methods in practice at well known companies through literature review and case study. Lamba and Singh (2017), review the existing application of big data analytics in supply chain management, and further point out the potential influence of big data analytics on facility layout, purchasing and distribution. Govindan, Cheng, Mishra, and Shukla (2018) summarize the wide applications of big data analytics in various fields of logistics and supply chain management, including supply chain traceability (Basole & Nowak, 2018), quick response evaluation (Choi, 2018), new methodology and capability maturity model of big data analytics (Arunachalam, Kumar, & Kawalek, 2018; Singh, Shukla, & Mishra, 2018).

There is also a stream of literature focusing on the impact of a firm's big data analytics capability on supply chain performance. Akter, Wamba, Gunasekaran, Dubey, and Childe (2016) first argue that big data analytics as a unique capability can help enterprises to establish sustainable competitive advantage, which is followed by a growing number of researches in this track, like Addo-Tenkorang and Helo (2016), Lamba and Singh (2017), Wamba et al. (2017), Moktadir, Ali, Paul, and Shukla (2019), Bag, Wood, Xu, Dhamija, and Kayikci (2020). Most of these studies show that big data analytics capability, as an integral part of enterprise organizational capability, plays an increasingly important role in improving supply chain performance. Moreover, they suggest that enterprises should deploy this capability from holistic view since the limitation of organizational resources usually hinders the construction of this capability.

The above analysis of the research progress on big data and operations management identifies the frontier of management issues related to big-data value creation in this paper. Different from the prior literature, the big data-driven supply chain operations in the embedded IoT environment that this study focuses on includes a new-type supplier of big-data service providers and its adjoint value chain, which changes the conventional supply chain structures. It makes the relationships among the supply-chain node firms more complicated, which engenders new management problems in the emerging situations as aforementioned.

2.4. IoT and supply chain management

There is a stream of literature exploring the impact of IoT on supply chain management closely related to the current study. Zhou, Chong, and Ngai (2015) is one of the early researches that point out the characteristics of the IoT as part of firm infrastructure are likely to improve system performance by streamlining processes and reducing costs and risks. There are a lot of work devoted to using IoT to improve the supply chain operations. Fang, Liu, Pei, Fan, and Pardalos (2016) study the optimal production optimization of a manufacturing and recycling hybrid system in the closed-loop supply chain under the environment of IoT. Gill, Phennel, Lane, and Phung (2016) develops an IoT-enabled information architecture to tackle the challenge of delivering the emergence information to elderly people effectively. Zhang, Zhao, and Qian (2017) report a conceptual model for the IoT-enabled perishable food supply chain, and validate the proposed model in improving the supply chain performance with a case study. Qu et al. (2017) propose a novel robust information structure and controlling schemes with cost-effective IoT solutions to deal with the challenge of managing an IoT-enabled dynamic production logistics system. A similar work is also shown in Tu, Lim, and Yang (2018). Muñuzuri, Onieva, Cortés, and Guadix (2020) address how to design an IoT system to automate data collection and processing in order to optimize port operation and multimodal transshipments, logistics and supply chain performance.

Some scholars have mentioned the concept of IoT based resource allocation related to cloud manufacturing. Zhao and Wu (2015) point out the development prospect of the IoT and its impact on resource allocation. In addition, Zhao, Du, Xu, and Yuan (2015) study the optimal strategy for manufacturing resources transfer between enterprises under the IoT cloud platform. However, research in this area is still in its infancy and needs a lot of investigation.

To develop more pragmatic approaches of supply chain performance measurement, Dweekat, Hwang, and Park (2017) introduce a novel structured method for IoT applications, while Rezaei, Shirazi, and Karimi (2017) develop an IoT-based framework of performance indicators based on Supply-Chain Operations Reference model (SCOR) metrics. Garrido-Hidalgo, Ramirez, Olivares, and Roda-Sanchez (2020) propose a circular supply chain framework as well as qualitative evaluation enabled by the adoption of IoT technology.

Some studies survey the theoretic progress on IoT and supply chain management. Ben-Daya, Hassini, and Bahroun (2019) discuss the impact of the IoT on supply chain management through literature review and bibliometric, classify the existing research and point out the future research directions to facilitate IoT implementation. In contrast, Manavalan and Jayakrishna (2019) propose a conceptual framework covering various aspects to assess service supply chain management (SSCM) for Industry 4.0 based on a literature survey. On the other hand, by offering a comprehensive review, Birkel and Hartmann (2019) derive a framework that relates he challenges of IoT to supply chain risks.

Some other research focuses on the obstacles of adopting IoT and the resulted impact on system function. Kamble, Gunasekaran, Parekh, and Joshi (2019) identify main factors hampering the incorporation of IoT in the retail supply chain in India, and explore their relationship. Legenvre, Henke, and Ruile (2020) conduct an empirical study of the positive effects of IoT on both procurement and supply chain management. All extant researches mentioned above have scarcely discussed the core content we just focus on here.

3. Research framework

3.1. Research background

In the above section, we have systematically reviewed the existing academic researches closely related to the study, including research on RFID and supply chain management, cloud manufacturing and cloud computing, and IoT-enabled resources allocation, big-data driven operations management. In the past decade, research in these fields have elaborated on the impact of vigorous development of information technology on operations and supply chain management from two perspectives of practice and theoretical exploration.

As for the research on RFID and supply chain management, there is a close connection between academic research progress and business practice. Although the IoT and RFID started proposed closely in time, the related research on IoT has rarely been seen in the past decade. This phenomenon is partially due to the relatively long-term silence in the IoT technology progress since its inception. Recently, with the breakthrough development of information and communication technology, the technical realization of the IoT becomes possible, and it has been applied in practice gradually but extensively. The industry, academia and governments began to pay great attention to the IoT. In sharp contrast, RFID as a key component of IoT has been widely used in industrial/commercial and military since its inception. Practitioners and scholars have observed and refined many meaningful research topics from a large number of practices. As mentioned earlier, research in this area has focused on inaccurate inventory, the bullwhip effect, and seeking optimal replenishment strategies.

Admittedly, the application of RFID has indeed affected the supply chain operations. For example, it can enhance the transparency of supply chains, which can make the decisions at operational and manipulative levels more accurate and effective. However, this effect is fundamentally different from the impact of the IoT on supply chain. In fact, we should first make clear that RFID is only a basic component of the IoT technology, and its role is only sensing and unidirectional information transmission. RFID does not have an intelligent decision-making function like the intelligent terminal of the IoT, whereas IoT can achieve bi-directional information interaction between machines. More importantly, the unique feature of IoT is the smart interconnection between intelligent terminals. In terms of functionality, the IoT has far surpassed RFID, and its disruptive impact on corporate behavior and supply chain operations. Furthermore, the intelligent interconnected products formed in the IoT have restructured the value chain in the supply chain network; the IoT technology environment impacts on consumer behaviors and value proposition hierarchies and products design; the SCPs arising from the IoT affect the supply chain network governance, coordination mechanism and operations optimization. The above issues can be considered synchronously from the perspective of big data analytics, which are not involved in the existing researches of RFID's impact on supply chain operations. Nevertheless, the study on RFID-related supply chain management still has a reference significance for our study on IoT-enabled supply chain operation in presence of big data services.

Although the realizations of cloud manufacturing, IoT and derived big-data analysis all rely on the cloud computing technology, there are fundamental differences between their focuses and core concepts. Cloud manufacturing mainly focuses on the allocation of resources in the network when the system decision mode switches between centralization and decentralization, with particular emphasis on the efficiency and technicality of resources allocation. While the focal IoT-enabled supply-chain operations here also stress resources allocating efficiency, we further consider the impact of the attributes of the rational economic individuals and the strategic interactions between chain agents on resources allocation outcome. Moreover, we emphasize the influence of IoT architecture and derived big-data analytics on the supply chain operational decisions, and discuss the relationship between them from the various aspects of economy, organization, system efficiency. These are beyond the topics in the cloud manufacturing situation.

The IoT-enabled big data-driven supply chain operations deeply involve data services, and IoT is embedded in entire process of supply chains, which changes the supply chain structure and triggers new network governance issues. The literature review has shown that some of existing big-data related researches give attention to technical discussion. Research from the perspective of IoT and big data embedded supply chain management needs to be enhanced.

From the foregoing survey and above analysis, one can find that the application of IoT can provide a new operating environment for supply chains. It has a profound impact on the entire process of the supply chain with non-linear effect on consumer behaviors and value proposition, corporate behaviors and supply chain structure, products' structure and value composition. These emerging changes lead to many new problems in the supply chain operations. How will consumer behaviors and value proposition hierarchies change in the IoT environment? How will this affect the co-creation behavior of product and service values of supply chain enterprises? What kinds of supply chain operational strategies will be required for big data-driven SCPs in the IoT environment? What are the characteristics of the supply chain scheduling and coordination of resource capabilities and the pricing of SCPs in the IoT environment? These are all emerging questions arising from the new management scenarios driven by the IoT and its derived big data services, to which the existing theory can hardly give answers. Focusing on both extensive literature review and existing practices, the goal of this study is to identify new theoretic challenges and carry out in-depth analysis on the emerging managerial issues as well as address the potential research directions in the IoT context.

3.2. Future research

The previous literature overview and practice-based analysis show us that there are some new features and emerging management issues arising from the supply chain operations driven by IoT and big data analytics, which the existing analogy theories are incapable of explaining. We schematically illustrate in Fig. 1 the operational scenario of supply chains enabled by the IoT to help better understand the IoT-triggered changes to traditional supply chains. We therefore summarize these features and issues in four aspects as follows.

First, compared with the non-IoT supply chains, the IoT and its derived big data analytics restructure the value chain and give birth to SCPs. As a result, the composition and proposition of product value change, which leaves a profound impact on the production and delivery of goods. In the IoT enabled environment, a variety of consumer products are widely interconnected to communicate with intelligent decision-making. The functions and values of these products together are forming the integral value consumers perceive. The interaction and integration of heterogeneous but complementary products and services correspondingly reconstruct the value chain, resulting in a new business ecological environment. In this environment, an enterprise's focus has changed from a single product itself to the IoT-enabled service based product portfolio, especially the intelligent interaction among products for service integration to meet consumers' needs. The big data analytics derived from these assorted components of SCPs will help to find the value forming dynamics of these diverse components and their impact on consumers' behaviors. This enables supply chain enterprises to better understand the values expression and coupling of heterogeneous product components in the process of forming SCPs, in order to better optimize resource allocation and production organization mode within and between supply chains.

Second, IoT leads to change in consumers' behavior as well as their value proposition hierarchy, which in turn causes supply chain enterprises to transform their product design patterns. With highly efficient and ubiquitous sensors and controllers, IoT has become a part of daily life for consumers and has direct influence on consumer lifestyle and habits. While the connecting devices themselves are becoming part of the service providers' network, consumers' behavior, consumption concept and value judgment system may also change greatly as a result. Compared with the non-IoT setting, the IoT-enabled widespread intelligent facilities make T2T and things-to-human (M2H) communication more frequent and convenient. Thus

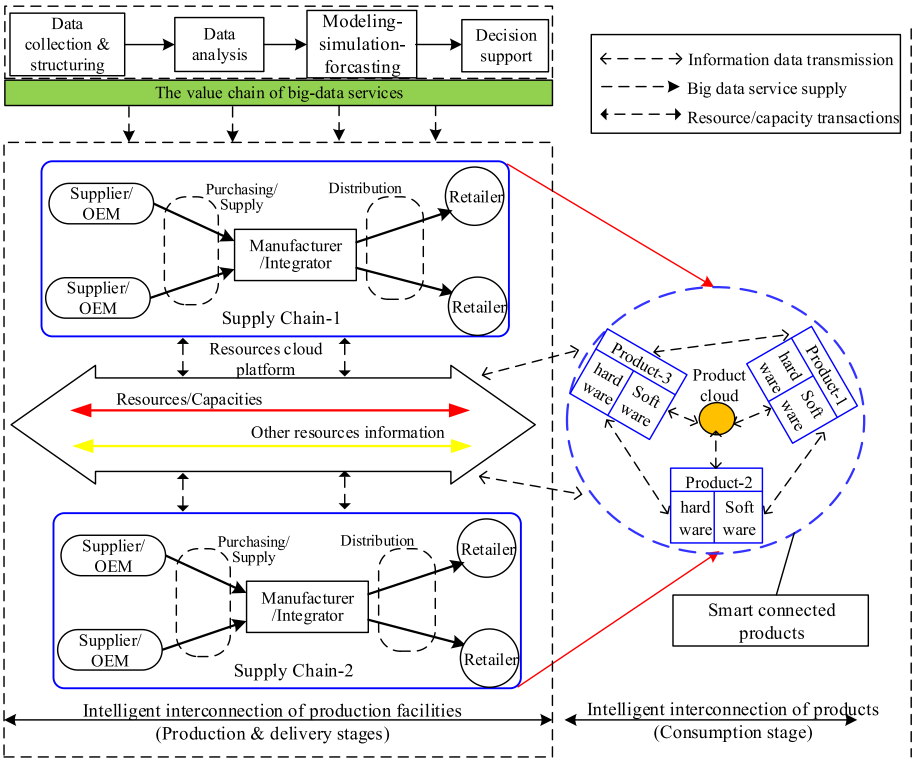

Fig. 1. Schematic big data-driven operations in the IoT-underlying supply chains facing smart connected products.

it is able to provide consumers with richer information and choices of products and services as well as even intelligent auxiliary decision-making aid. This generates new value propositions for consumers. On the other hand, the T2T and M2H communications make it possible for consumers to participate in real-time decision-making via interactions with smart devices and even the entire IoT. Meanwhile, the substantial change of consumers' value judgment makes it prominently different from that in the traditional human-human (H2H) interaction mode. In the IoT embodied supply chains, how to adjust enterprises' decision making and products/services design pattern to effectively respond to the such changes presents new challenges for researchers and practitioners.

Third, although the IoT enables enterprises and their supply chains in a much larger spatial and temporal scope to access and allocate resources and capacities, it is fairly challenging to dynamically allocate the resources and capacities both efficiently and effectively. In the IoT environment, the production facilities belonging to different enterprises can have intelligent interconnection across walls of firms. This therefore enhances the possibility of real-time and dynamic transmitting of the internal data information of manufacturing resources inside separate firms, raising the visualization degree of resources and transparency of supply chains. These in turn would typically lead to extensive personalization and customization as well as decentralized or distributed production. Since the data information of demand and production status will be transmitted constantly and updated dynamically, IoT will empower supply chain firms to mobilize manufacturing capacity and resources in a broader geographical space and a more precise time range. In particular, it becomes possible for a firm to use the idle/surplus manufacturing resources and capabilities of other firms in the supply chain network, which can improve the utilization rate of resources in the network and reduce the marginal cost of production. In response to data analysis of demand and updates of resource utilization, production plans and capacities needs to be adjusted constantly for the focal SCPs. To this end, managing the process of dynamic deployment, scheduling, optimization and coordination of the resources and capacities stretching across IoT linked enterprises and products with multiple values intertwined is much more complicated and challenging than the traditional production management.

Lastly, the IoT derived big data service changes value chain and supply chain structure, incurring new problems of supply chain operations coordination and governance mechanism on data sharing among these node firms. In IoT environment, there basically exist two kinds of big data related firms, big-data owners and big-data service providers. The latter firms have professional skills in big data processing and analysis. Big data service providers create value through processing data, knowledge mining and eventually contributing to effective decision support. The presence of big-data service providers essentially changes the existing value chains and supply chain structures, which initiates new issues of supply chain structures choice and incentive contracts design. In addition, although the IoT-enabled real-time transmission of data information raises visualization level of production resources and capacity of the supply chain nodes, the scope and degree of data sharing often occupies a priority of the firms involved for security reasons. In this context, the governance mechanism of big data sharing among channel agents determines the operational performance of supply chains, and accordingly brings about many emerging problems of competition and cooperation on utilizing data.

The above summarizes the new features and problems of supply chain operations based on IoT and its derived big data analytics. As the IoT and big data technology have been gradually applied to specific business practices in recent years, a lot of explorations beyond the existing theoretical research is needed to explain the aforementioned emerging challenges for management problems in this new context. This status quo therefore inspires the following elaboration on potential research directions.

Prior to addressing the potential research details, we sum up all the discussion previously to furnish a framework for future theoretical developments and extensions. Motivated by the IoT enabled big-data driven supply chain scenario, the proposed framework aims at guiding the research directions. These research directions include revealing the optimal strategy and mechanism of system operations, analyzing the role of IoT and big data analytics in consumers' value proposition hierarchy and product characteristics mapping, and exploring the governance and contrivance of big data sharing and the methods of resources integration. Notably, we propose these aspects as potential research directions due to the following three reasons: First, these research directions are extracted from and can reflect the radical changes brought by the IoT and big data analytics to the supply chain operations and can reflect the changes well; then, these four aspects consist of the demand identification and product design, resource allocation optimization, production and pricing, supply chain coordination, which covers the most core and important areas of operation and supply chain management; and then, typical practical cases just support and inspire these research directions. In addition, research developed from the proposed framework is supposed to utilize the IoT enabled big-data driven supply chain system as a carrier and transmission instrument, providing references for policy making for this field.

Resembling Lee and Tang (2018), we use the pattern of describing relevant industry practices first as motivations of the proposed research directions prior to deploying the corresponding theoretical analysis in the following sections.

4. Big-data driven consumers' value proposition hierarchy and mapping model for products features in IoT-enabled supply chains

Holbrook (1994) states that customers may have the interactive and relativistic preference that characterizes their experience of interacting with some object. This statement apropos reminders that we should concern the consumers' value proposition hierarchy since the proper comprehensive assessment of products and services should arise from an ensemble of diverse judgments on various levels of merits, attributes, values and other factors affecting customer experience (Iacobucci, Grayson, & Ostrom, 1994; Mattila, 1999). Below we discuss two cases relevant to this proposed research direction.

Case 1. *Interconnection Program of Intelligent Home Appliances*. This case is described in detail in MHA (2017) and Li (2018). Under the leadership of the China Household Electrical Appliances Association, seven well-known companies including Haier, Midea, BSH, Hisense, Changhong, Skyworth and TCL set up the "Smart Home Appliance Interconnection Project Working Group" in 2015. These companies also formulated the common standards for open cloud interfaces that apply to and connect various products offered by these companies. End users can then use the smart applications of the cloud platforms to add and control those smart home appliances via the operating interface. The household appliances involved include refrigerator, washing machine, room air conditioner, air purifier, water heater, range hood, coffee maker, dishwasher, electric oven, televisions, etc. In the daily usage setting, this will change the isolated original intelligence systems of home appliances into an interconnected and interactive system, which allows the end users to better enjoy the convenience and comfort offered by a variety of appliances. Therefore, not surprisingly, the Appliance & Electronics World Expo. (AWE) 2018 was a showcase of intelligence, living scene orientation, user friendly and seamless integration and connection. In short, the goal is to build a better business ecological system that facilitates integration of the products from different companies with the goal to create win-win scenario for all parties involved. In addition, the project also addresses the security aspect of the overall interconnection scheme with specified security standard, protocols for the access authentication, permission of the control of interaction functions, and confidentiality of personal data transmission.

Case 2. *Haier Smart Home*. We draw this case from Chen (2017). Haier, a Chinese famous household appliances giant, released the world's first smart home program just before AWE 2017, involving the first 161 smart living scenes in different physical spaces in living room, kitchen, bathroom and bedroom. The Haier smart housekeeper platform to which the program belongs has created five ecosystems, namely, kitchen, bathroom, living, entertainment, and security, providing consumers better services and experiences. Various smart home appliances that use Haier's "U+" operating system can interact with end users through multiple interfaces such as mobile phones, refrigerators, TVs at different locations such as kitchen, living room and bathrooms to customize users' experience. Real-time interconnection allows home appliances to offer personalized services tailored to meet individual needs. This platform aims to respond to the diverse life scenarios proactively. Furthermore, via real-time interconnection between end-users, products, robots, and production lines, consumers can participate in the entire process of product design and manufacturing, and thus become an integral part of the production and consumption of goods and service for customized experience and higher customer satisfaction.

4.1. The IoT-enabled approach of mapping consumers' value proposition to product features

Porter and Heppelmann (2014, 2015) have given a pioneering introduction on the concept of SCPs, which is triggered by IoT technology distinguishing from traditional products in physical composition and value creation. The IoT-based T2T enables a network of independent intelligent terminals of products and service to become the so-called SCPs through their mutual communication and data transmission. This kind of information and data interactions makes those diverse functions and values coupled and integrated, and forms the consumers' perceived value. Therefore, IoT technology expands the independent single-dimensional values of traditional isolated products and services to the multi-dimensional diverge value system of SCPs.

On the other hand, the complex system of SCPs empowers consumers' deep participation and involvement by operating the product or co-producing services and sharing their reviews and feedbacks instantly and dynamically (Maass & Varshney, 2008; Zinkhan, 2003). During this process, SCPs' running and customers' experience gradually generates big data. Differing from traditional situations, the IoT-enabled products intelligent interconnection makes consumers' utility largely stem from the multi-dimensional functions and services resulting from the intelligent communication links between heterogeneous related products. Therefore, compared with the traditional situation, the SPCs in IoT environment has substantially changed the consumption situation, consumers' behaviors, the production pattern of product and services, the source and composition of product value. Accordingly, consumers are likely to establish a fresh value proposition hierarchy about the new-type products and services.

After observing the change of consumer value proposition hierarchy, enterprises and their supply chain partners will reflect this change in product feature design to effectively cope with the change effectively. However, this kind of change cannot be directly equivalent to the change of demand for product characteristics. In addition, we need to consider the collaboration and efficacy of SCPs. In light of the synergy and influence of the values of multi-product intelligent interconnection, the traditional approach of mapping consumers' behavior characteristics to firm's product design no longer works effectively for the SCPs case. Therefore, it is necessary to recognize the change of consumers' value judgment on the specific IoT-based products and services and transform it into strategies of products design for IoT-enabled supply chains.

Generally, the SCPs' value proposition for consumers feature the multi-dimensional values and synergy of the network. The big data generated in the whole process of the SCPs running as well as consumers' participation and experience is multi-source, heterogeneous and interactive. Hence, the big data analytics may well deconstruct the consumer value proposition hierarchy in this context.

The logic of this research direction can be described as follows. Based on big data analytics, a new framework of value judgment system for consumers in the IoT environment need to be reconstructed. And the key elements and control dimensions of the framework may be identified. This will provide the basis for depicting SCPs' values composition and the associated transfer process. The SCPs' value coupling in function and utility of heterogeneous products for the consumers is likely to affect the assorted products' designs and the coordination of their affiliated supply chains. In this situation, the consumers' value judgment system can deconstruct this kind of value coupling. Accordingly, the mapping approach can transform this evaluation system into products feature design scheme. This kind of mapping model can be developed through big data analytics.

To this end, this research direction proposes to study the qualitative and quantitative aspects of the composition of the consumers' value judgment system in the context of the IoT, and carry out the corresponding control dimension analysis. More specifically, the following research directions can be pursued: (1) evaluation and analysis to develop the value appeals of SCPs driven by big data to consumers; (2) To build the framework and conduct control dimension analysis of consumers' value judgment system based on big data analytics; (3) big-data driven exploration on multi-dimensional values ranking and composition of SCPs based on consumers' value judgment system; (4) the mapping model and relationship between consumers' value judgment system and enterprise product characteristics in IoT environment.

4.2. Alternative research and discussion

Prior to constructing the framework of consumers' value judgment system through big data analytics, one needs to collect the massive real-time data produced by running specific SCPs and consumers' interaction and participation. Based on the framework of consumers' value judgment system, it is of value to devise the multi-component multi-dimensional value ranking system of SCPs and to study the synergy of the values from the multi-dimensional values as well as the systematic evaluation of the multi-dimensional values. According to ranking and evaluation result, one can develop the mapping model for connecting big-data driven consumers' value judgment and firms' product characteristics design in IoT environment, with details on the transformation process and method.

5. Big-data driven modeling and optimization of dynamic resources mobilizing in supply chains

Case 3. *CASICloud's Cloud Factory Program for Intelligent Manufacturing of Automotive Stamping Die*. This relevant case is reported in CASICloud (2019). In its early stage, an automobile die company, constrained by equipment capacity and management level, was unable to meet demands from all around the globe due to low utilization equipment rate and insufficient production capacity. Previously, there was no integrated management system to cover all aspects of manufacturing, delivery, order management and fulfillment. To solve this issue, the company applied CASICloud's industrial intelligent cloud system (INDICS) platform to build an intelligent manufacturing cloud factory that integrates both the intelligent manufacturing process within the firm and the corresponding collaboration among its partners. Based on the INDICS platform, implementing the cloud manufacturing application establishes a public service platform for sharing manufacturing resources of automobile stamping dies. This platform connects many scattered social manufacturing resources together for open cooperation and intelligent sharing to provide various re-organized manufacturing services. The intelligent-manufacturing cloud factory has innovative features such as collaborative manufacturing, integrated management of overseas orders and visualization of the factory's global supply chain, rapid response to orders and intelligent production in workshops. In terms of economic benefits for the firm, this program is estimated to lower the operational cost by 20%, shorten the product development cycle by 30%, reduce the quality problems by 10%, increase the resource utilization rate by 15%, cut the labor force by more than 70%, and elevate the efficiency and production capacity by more than 30%.

Case 3 is related to the theme of this section, and provides background and implications for the subsequent analysis.

5.1. Big-data driven dynamic resources allocating in supply chains with SCPs

This direction focuses on the production and supply side of the IoT-enabled supply chain. That is, this part pays close attention to addressing the research direction of pursuing optimal mobilizing and scheduling supply chain resources and capacities in the environment of IoT. As discussed above, the value of SCPs for consumers in IoT setting lies with the resulting intertwinement of various components. Without it, the production of different SCPs component is done with resource allocations only based on information and structure of the product's own supply chain, which misses the benefit of the synchronization in the IoT environment.

More significantly, similar to the consumption end, the production and service facilities in IoT-enabled supply chains also have intelligent interconnection. The internal manufacturing resource data information of upstream and downstream enterprises in the supply chain can be transmitted within supply chains in real time and dynamically, which can greatly improve the visualization of resources in supply chains. At the same time, the data information of demand and production status can be transmitted instantly and updated dynamically, which makes it possible for supply chain enterprises to mobilize manufacturing capacity and resources in a broader geographical space and a more precise time range. In particular, enterprises can use the idle manufacturing resources and capabilities of supply network nodes to improve the utilization rate of supply chain resources and reduce the marginal cost of production.

However, the IoT-enabled T2T interconnection of facilities lead to the sink of supply-chain nodes from firm level to the resource ends. This fact allows the enterprise to optimize the allocation of resources with the information at resource level. On the other hand, the accurate and personalized data generated in the process of consumers' experiencing SCPs is also dynamically shared and creates feedback in real time. Consequently, the supply chain of each individual component in the network of SCPs can obtain big data about both manufacturing resources and demand features. Various components form a network of SCPs through functional collaboration and value coupling, which requires collaborative scheduling and optimization through the dynamic allocation of resources among supply chains. In this situation, the dynamic scheduling, optimization and coordination of the resources and capacities for the products with many firms within a larger space-time range are more complicated and challenging, compared with the traditional case.

The logic of this research direction is deployed as follows with a schematic description shown in Fig. 2 for adjuvant explication. In the IoT environment, the data information about resources and capacities of enterprises will be transmitted instantly and form big data in the supply network, which creates favorable conditions for supply chain agents to seek manufacturing resources allocation in a broader time and space. Moreover, the IoT based T2T empowers enterprises to allocate resources at capacity unit level. Therefore, it is necessary to optimize the scheduling of supply chain accessibility based on the big-data analysis of demand features change and network resources in IoT environment. To this end, the key is to build the scheduling model for the associated big-data driven supply chain and its corresponding algorithm.

One potential research attempt may be to consider the SCPs with two heterogeneous product components. Focusing on the supply chains of the two products, one may explore the dynamic mobilizing and configuration game of supply chain manufacturing capacity in IoT environment. Other relevant topics include optimization algorithm for the scheduling (Hall & Potts, 2003), and dynamic game model of resource allocation.

5.2. Alternative research and discussion

Taking some specific SCPs of consumer electronics as an example, we propose to conduct analysis on the real-time dynamic state of resource capability in the supply chain, construct its allocation models based on supply chain scheduling theory, and design the corresponding optimization algorithm. Furthermore, considering the value proposition and function integration of the SCPs, a resource scheduling model can be further constructed based on the structure and value composition of SCPs. Lastly, the game equilibrium of resources allocation competition among the supply chains that individual components belong to can be studied using differential game theory.

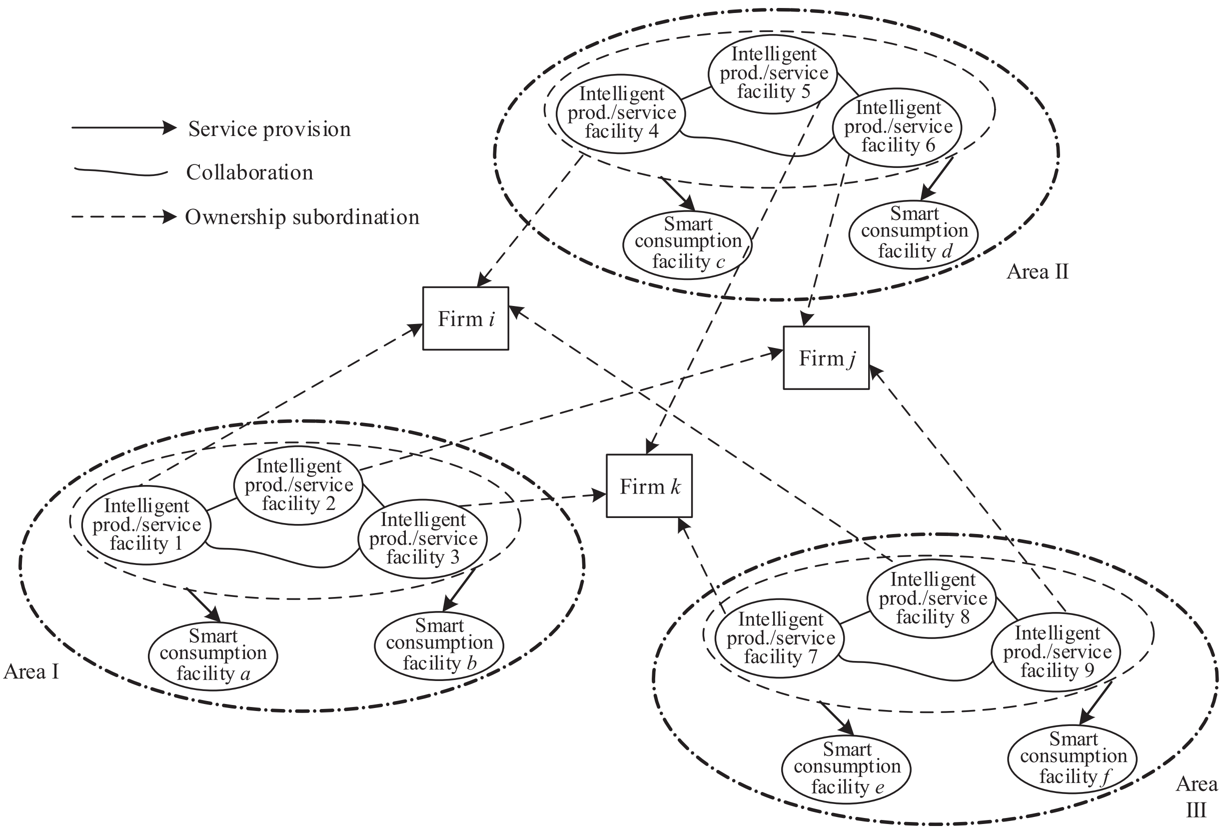

Fig. 2. Schematic resources mobilizing and allocation in the IoT-enabled supply chains.

6. Big-data driven dynamic strategies of production and pricing under products' intelligent interconnection

Case 4. *Crossover and Integration of Intelligent Manufacturing and Smart Home in China*. As a leading mobile phone manufacturer and operator in China, Xiaomi considers smart home as one of its important breakthrough directions when facing the gradual decline of the smart phone market. As a result, Xiaomi has constructed by far one of the most comprehensive smart home ecosystem with its outstanding manufacturing and delivery might. Recently, Xiaomi established a joint venture with Philips Lighting to introduce the latter's intelligent connected LED products into the former's smart home family (Sijie, 2016). Not only that, the companies attached to Xiaomi have launched a variety of new home appliance products beyond Xiaomi's traditional smart phone business, such as intelligent devices of rice cooker, electric kettle, desk lamp, air conditioner, and sweeping robot, which reflects Xiaomi's ambition in the field of smart home (Elecfans, 2016). The ecological-chain system of Xiaomi consists of more than 70 companies from the following areas: mobile phone peripheral (e.g. headset, mobile power and Bluetooth loudspeaker), intelligent white home appliances (e.g. air and water purifiers), intelligent wearable equipment (e.g. smart bracelet and watch), and entertainment products (e.g. balance car). Actually, Xiaomi's intelligent home product family has become one of the most comprehensive intelligent home appliance ecosystems in the world (Ofweek, 2017). Xiaomi's founder Jun Lei stated that "Our idea is to use the Xiaomi model to enter one hundred segments, promote the intelligent home appliance product family, and turn Xiaomi from a big ship to a fleet" (Lei, 2017). Finally, Xiaomi's smart home appliance ecosystem provides end users smart and connected products, intelligent interconnection of which elevates individual values of products and also brings quality improvement and cost reduction. In addition, the deep integration of intelligent manufacturing and home appliance industry has transformed home appliances from traditional simple household tools into a high-tech systematic solution for better life quality and more convenience. Another example, Changhong, an established TV manufacturer in China, put TV equipped with artificial intelligence (AI) and other home appliance products such as air conditioner, sound, light, curtain, and security systems together to create an integrated and innovative experience for the end users. Through the AI voice enabled interaction, the TV with other connected home appliances and products can create a family gym, home theatre and TV shopping mall for the user and deliver an enriched experience (Li, 2018). Furthermore, another big Chinese home appliance manufacturer giant, Haier, has built its own smart home ecosystem with a network of connected factories on the supply side and SCPs on the product side. Meanwhile, the end users play the dual roles as both consumers and producers bridging the two sides. As a result, customers' needs are satisfied through interconnections and interactions among people, machines and things (Chen, 2017). Rooted in Case 4, we give the following statement.

6.1. Game theoretic analysis for joint optimization of production and dynamic pricing in IoT-enabled supply chains

This direction looks at the production/service provision and its dynamic pricing in the IoT embedded supply chain, in which the IoT technology makes the data information in the supply chain can be transmitted and interacted dynamically in real time. Accordingly, big data becomes an important resource factor of supply chain operations. In this situation, big data flows lead the upstream and downstream enterprises of the supply chain encounters to make fundamental changes in decision making regarding the choice of mode for production/service and pricing. For example, utilizing the huge data from the downstream clients, the upstream suppliers have the opportunity to provide value-added services. One such example is the GE and Alitalia cooperation[3] (Porter & Heppelmann, 2014; Yamazaki & Tanaka, 2015) and Cadillac services. Based on data analysis of clients' operating and pricing, the upstream enterprises can may adjust their own production/service for output, inventory and service level in a timely fashion while offering monitoring and feedback service to help clients to improve their efficiency.

On the other hand, IoT enables enterprises to apply real-time dynamic pricing of products for profit maximizations based on data analysis since it grasps real-time dynamic data of demand side. There are significant distinctions between the SCPs in IoT environment and traditional ones in dynamic pricing for the following reasons: (1) SCPs equips decision makers to capture the latest state of the supply and demand of resource capacity in real time; (2) Multiple products with intelligent interconnections need to provide customers functions and services of comprehensive multi-dimensional value together, which requires synchronization of a variety of products across firms.

As a result, these decentralized self-interest enterprises will play dynamic pricing games in light of interconnections of their value propositions. The dynamic pricing of intelligent products in this new situation may request to adjust the supply level of resource capacity and products characteristics so as to better match supply and demand. Examples in practice include the cases of Macy's and DiDi.[4] Another strategy could align the diverse elements of the price vector of SCPs' components and devise appropriate pricing strategies according to different market segments so as to obtain high premium. Both of these two strategies could contribute to maximize the utilization and value of the existing resources and capabilities of the entire system.

The reasoning for research along this direction could be as follows. The IoT technology enables the real-time transmission and accumulation of data on resource capacity and product status in supply chain nodes. The resulted big data analytics therefore will have a significant impact on the production and pricing of supply chains. On the one hand, the IoT empowers enterprises to analyze the massive real-time data from the demand end and the SCPs to implement dynamic pricing of products to maximize the benefits. This is what happens to the profit aspect of the supply chain. On the other hand, suppliers/manufacturers in supply chains, often considered as the cost centers, now have the potential to adjust their production/service input according to the change of demand and resource capacity with unprecedented precision and response speed. Therefore, for the entire supply chain, it is necessary to achieve the joint optimal strategy through big data analytics, aiming at optimizing the performance of supply chains via matching the resources acquisition and products/services demand.

To investigate the key problems discussed above, the specific research in this area can be divided into the following two types: Game theoretical analysis of production/service via dynamic pricing of two-tier supply chain considering the intelligent interconnection of the products driven by big data; and joint optimization for production/service via dynamic pricing of SCPs supply chain.

6.2. Alternative research and discussion

Based on the discussion above, certain alternative research directions can potentially be investigated with the following scheme. First, take the two-tier supply chain composed of suppliers and manufacturers in the IoT environment as the research object, and analyze the accumulated massive real-time dynamic data to describe the supply chain production/service function in this scenario. Second, establish a dynamic pricing revenue function for downstream enterprises in the IoT environment by analyzing big data on the demand side. On the basis of the above, one can construct the dynamic differential game models of production or services and dynamic pricing for the supply chain, and then give the production and pricing trajectory functions of the upstream and downstream enterprises after getting the game equilibriums.

[3] For example, the engine provided to an Italian airlines company by GE Aviation has lots of sensors. GE uses the sensors to collect data to optimize the function of the engine and provide fuel data to the airlines which helps to the downstream company to improve its operation and cut costs.

[4] For example, Macy's real-time pricing mechanism. Based on demand and inventory conditions, the company adjusts real-time prices for up to more than seventy million items based on SAS systems. Another case, Didi, the largest car-hailing company in China, integrates the demand and supply information to the cloud platform. They can implement dynamic price increases based on real-time changes in transportation capacity (number of vehicles) and order characteristics (ride demand) in the customer's area. Meanwhile, they also provide a variety of service forms such as downwind cars as well as dynamic pricing strategies.

7. Relational contract arrangement and big data sharing mechanism in supply chains with IoT

Case 5. *Opportunities and Challenges for Big-data Enhanced Maintenance Repair and Operations(MRO) Management in Aviation Supply Chains*. This case is adapted from Canaday (2017), Porter and Heppelmann (2015) and series reports in ICF (2020). From Chen, Gusikhin, Finkenstaedt, and Liu (2019), the MRO are essential to aviation industry operation. However, the high uncertainty and irregular lead time of MRO spare parts have created unique challenges for MRO management. Fortunately, a company can use predictive maintenance technology based on big data analytics to tackle this challenge and the estimated savings in maintenance costs could exceed $3 billion totally. Actually, an aviation supply chain typically includes aircraft engine companies (e.g. HP), aircraft integration manufacturers (e.g. Boeing), airlines and their affiliated MRO companies, third-party MRO providers and other service supporters (e.g. Honeywell). As a result, the huge data predictive maintenance technology depending on is generated by all these companies involved in an aviation supply chain. Typically, engine companies and aircraft OEMs have been collecting data from their own manufacturing and testing processes using sensors and other data collecting devices installed on their products. MRO firms affiliated to airlines and third-party MRO providers have accumulated a lot of operations and maintenance data during their long time partnerships and services. Similarly, other service supporters also have obtained huge data in their own way. Airline companies' operation and maintenance data are useful for upstream main suppliers as well as the operations and maintenance suppliers to improve their product and service quality. In the meantime, manufacturing and testing data generated in the upstream of the supply chain are very helpful for optimizing downstream operation and maintenance. Nevertheless, there are many contests on data ownership, the choice of data accessibility and the degree of data sharing. It is necessary and challenging to devise supply chain institutional arrangements or contracts which can deal with these issues adequately. These agreements or contracts are expected to affect the value and utilization of huge data, supply chain risk control, individual and system performances, and etc. In addition, as the time goes by after the aircraft is in use, both the data demand and the power balance among all players on the supply chain could shift and creates uncertainty and instability. In reality it is common different parties have different goals for the collaboration. Typically, HP is particularly committed to using data to improve the safety and reliability of its engines. For this purpose, an interdisciplinary task force has been set up to focus on data sharing and best practices. HP would advocate effective access to data, and argue that data ownership should vary according to data type, contract and partner ownership. For example, Honywell has attempted reaching data sharing agreement with airlines to install sensors on its products to collect aircraft and engine data to provide operational support services. From Case 5, we address the relevant analysis as follows.

7.1. Supply chain structure selection and incentive mechanism considering IoT-enabled big-data services

In the IoT environment, the intelligent interconnection of heterogeneous products and manufacturing facilities creates big data in real-time during the dynamic process of running the system,[5,6,7](Gartner, 2016; Marr, 2015; Mayer-Schönberger & Cukier, 2013). In order to discover and fully utilize the value big data, high-quality professional processing of the data is the key. In particular, to gain the benefit of big data for profit increase, it is crucial to improve a company's data processing capability and adds value in the process.

Accordingly, big data in IoT environment has become an important strategic asset for enterprises. In practice, some companies have chosen to build their own in-house data processing capability aggressively; while others chosen to use third-party services for their data processing. The emerging value chains related to the analysis on the massive data generated by IoT and cloud computing are often embedded in the original supply chain of products and services, forming new functional nodes and profit modes based on big data business, which are likely to change the original Supply chain structure and transaction relationships (as shown in Fig. 3).

In this context, one of the problems facing enterprises is to determine the influence of data on value creation. One big challenge is to determine the connection between data type and value creation or value adding. Evaluation models that allow the firms to evaluate such connections are needed for their decisions regarding data types in structure design and etc. Another important decision is about the use of the big data as an important production resources. Enterprises can choose to sell the data, or use the data to expand and engage in new businesses, such as providing valuable value-added services driven by the big data on customers. Research is needed to study the tradeoffs involved in these decisions.

However, sharing data could be risky for organizations for property data involved. The common belief is that data sharing among the upstream and downstream parties on the supply chain enabled by IOT should be beneficial for better supply chain performance. However, trust issue and interest conflicts often create obstacles for achieving such benefits. To maximize the

[5] Gartner (2016) defines "big data" as a massive, high-growth, and diverse information asset that requires new processing models to have stronger decision-making, insight, and process optimization capabilities.

[6] Big data in Mayer-Schönberger and Cukier (2013) refers to the use of all data for analysis and processing without using shortcuts such as random analysis (sampling survey).

[7] Marr (2015) proposes the characteristics of big data 5 V: Volume (mass), Velocity (high speed), Variety (diversity), Value (value), and Veracity (reality).

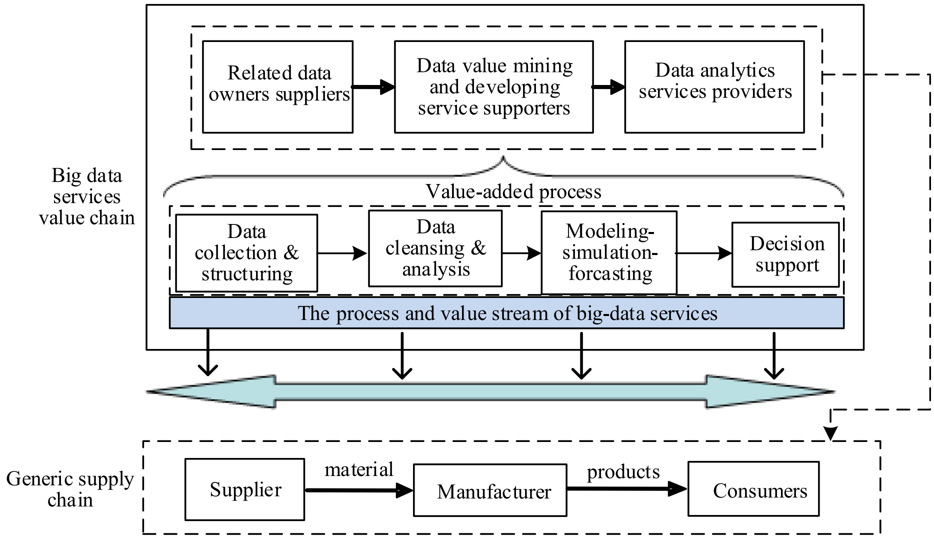

Fig. 3. Schematic IoT-enabled supply chain in presence of big-data services. providers and value chain.

efficacy and effectiveness of IoT, it is therefore necessary to design proper incentive contracts for data sharing, pricing and profit allocation to coordinate the interests of all supply chain parties with incentive compatibility and participation constraint satisfied.

Moreover, the third-party big-data service providers can provide value-added data processing services for the supply chain enterprises. At this point, different supply chain structural arrangements between the big-data service providers and the original supply chain enterprises will also affect the performance of the entire supply chain.

In short, the supply chain operation performance in the IoT environment will be affected mainly by two aspects: the design of incentive contracts for real-time data sharing, pricing and transaction mode between the upstream and downstream parties of the supply chain, and the supply chain structural arrangement with third-party big data service providers. Research in this area can be developed along the following three directions: (1) To develop the theoretical framework and evaluation models for the connections between data type and valuing creation in a typical IoT-enabled supply chains; (2) To build game-theoretical models and incentive contract models for dynamic data sharing and pricing within supply chain in the IoT environment; (3) To study the impact on operational performances of different supply chain structures with third-party big-data processing service provider; (4) To devise the optimal design of channel structure and vertical incentive contracts in supply chains with third-party big data service providers.

7.2. The governance mechanism for big data sharing in IoT-enabled supply chains based on relational contract

In this section, we shift our focus from overall contract design with complete contract to the governance mechanism design of big data sharing under incomplete contracts.

In the IoT environment, real-time and dynamic data transmission (eventually forming big data) greatly improves supply chain's capacity and efficiency to deliver optimal performance for production and service.[8] Meanwhile, it has led to a new operational mode in which a product's ownership and usage right can be completely or partially separated.

The main obstacle to the application of big data in the IoT-enabled supply chain operations comes from the volatility and limited availability of data. With the emergence of big data, an aggregate data set is more valuable than any individual part of the set. Given the higher value of the entire data set, the data sharing mechanism for the supply chain or network has a great impact on the performance of the supply chain. The governance mechanism of data sharing can be described by cooperative games in a clear or fuzzy situation, respectively. All parties make their own judgment on the cost and benefit of the alliance and data sharing mechanism. Accordingly, in the new IoT setting, the design of the incomplete contract and the data-sharing governance mechanism play a decisive role in the final performance of big-data driven supply chains.

Network organization governance is a kind of relationship arrangement focusing on corporate institutional arrangements among participants consisting of organizations and individuals via contracts and social connections. Hence, naturally, contracts and ownership are powerful tools for devising supply chain relationships. Baker, Gibbons, and Murphy (2002) define relational contracts as "informal arrangements maintained by the value of future contractual relationships." They further

[8] Because the data of product use can be obtained directly, then the fault can be predicted/reduced and repaired, and the product performance can be adjusted and optimized.

point out that the essence of network organization is largely the connection of relational contracts, and proposes the BGM network governance structure.

From the perspective of network governance, the research direction described above suggests the use of relational contract theory to study the coordination of supply chain operations with relational contract and data sharing governance mechanism in the IoT environment. The potential research can reveal the impact of institutional contract design and data sharing governance mechanism on supply chain performance, and eventually seek the optimal design of big-data sharing schemes and relational contract. This research direction lies in the intersection of industrial organization theory, cooperative game and supply chain management. A possible research framework could entail the followings: (1) To compare the operational performance of supply chain with different relational contract arrangements given data sharing mechanism; (2) To explore the relationship between the big-data sharing mechanism and supply chain performance under specific relational contract; (3) To match the relational contract and the degree of data sharing in an IOT environment.

In summary, from the perspective of industrial organization theory, relational contract is an important tool to describe the relationship between upstream and downstream enterprises in supply chain in the IoT environment. A variety of relational contracts and different levels of big data sharing among the parties on the supply chain form diverse combinations of the two elements, which accordingly lead to different operational performances of IoT-enabled supply chains. Thus, by comparing the performances of supply chain operations in different situations described above, it is possible to find the best fit between relational contract design and big-data sharing mechanism to achieve the best supply chain governance effect.

7.3. Alternative research and discussion

In this section, we outline an alternative research direction for supply chain structure design and incentive mechanism for big data services. For the typical supply chain with big-data services in the IoT environment, the first step is to develop an evaluation model and classification framework for "data types—values added". Then principal-agent models can be deployed to study big-data service providers' involvement in different stages of the supply chain. Furthermore, the optimal design of supply chain coordination mechanism to match the different combinations of vertical data-sharing incentives and third-party big-data service involvement in supply chain should be developed with tools possibly from game theories and other fields.

Another relevant potential research direction is the governance mechanism design of big data sharing in IoT-enabled supply chains with relational contract. Specific research topics along this direction include: to apply relational contract modeling to model different relationship types of supply chains in the IoT context; to model the governance mechanism of supply chain network based on relational contracts and data sharing levels, and to compare the supply chain performances with different levels of data sharing. Finally, based on previous researches, it is also of value to build a framework that connects relational contract types, big data sharing levels and supply chain performances, and to develop effective and reliable big-data sharing mechanism of supply chain based on cooperative games.

8. Concluding remarks

The emerging practices stemming from the worldwide disruptive technological wave actuated by the application of IoT have confronted the academia and practitioners with challenges to understand the impact of the phenomenon on managerial practices regarding supply chain management.

Different from the extant literature in the field of information technology and supply chain management, the current study specifically focuses on exploring the principles and internal mechanics of big-data driven supply chain operations in the IoT environment. In particular, it shows that the IoT architecture affects customer behaviors and value judgment, firms' production organization modes and supply chain coordination mechanism. By closely examining the relationship between IoT and big data, the current study investigates the impact of IoT on consumers' behavior and supply chain operations from the perspective of big-data analysis. It explores the all-round influences of IoT and the big data generated by IoT on the operational decisions of supply chain t and elaborates various potential research directions that address some of the most critical influence, dynamics and mechanics of IoT and big data analytics on the operations and management of supply chains.

This study makes the theoretical contribution in several aspects. First, it proposes to study the profound changes of customer behavior and value judgement led by IoT architecture, and develop the corresponding mapping models using big data analytics to incorporate such changes into the enterprises' decision-making for products characteristics. Second, the current study offers insights on how the inner connections between consumers, products and organizations make big data a crucial factor for production, value creation, organizational boundaries and value chains. This insight is derived from the characteristics of IoT-enabled SCPs. It inspires the potential study of the big-data driven optimization on dynamic scheduling of manufacturing resources and dynamic pricing of production and service. Third, the current paper elaborates future research on optimal fit between supply chain structure and vertical incentive contract design in the IoT-embedded supply chains with big-data service providers involved. At last, the current paper prescribes potential research on the governance mechanism of big data sharing in supply chains with IoT based on relational contracts theory. The goal is to optimize the match between the relational contracts and the big data sharing mechanism that solves the cooperative problems and improve the performance of big-data driven supply chain operations.

This research is also highly relevant to practice and provides a theoretical reference for operational decisions of enterprises for their supply chain management in the IoT context. Firms and their supply chain management can better understand consumers' behaviors and value judgments, and adjust their operational strategies accordingly. In addition, this study can serve as a valuable reference for governments to formulate public policies and regulations for the industry of IoT and big data. The future exploration along the proposed potential research directions can aid governments' promotion of the integration of industrialization and digitalization and the new industrial transformation and upgrading.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

The authors sincerely thank anonymous reviewers and editors for their time and effort devoted to this paper. Their constructive comments and suggestions are very helpful to the paper's improvement. This research is partially supported by National Natural Science Foundation of China (NSFC) Grants (Nos.91646118, 71501108, 71602142, 71701144).

References

Addo-Tenkorang, R., & Helo, P. T. (2016). Big data applications in operations/supply-chain management: A literature review. *Computers & Industrial Engineering, 101*, 528–543. https://doi.org/10.1016/j.cie.2016.09.023.

Akter, S., Wamba, S. F., Gunasekaran, A., Dubey, R., & Childe, S. J. (2016). How to improve firm performance using big data analytics capability and business strategy alignment? *International Journal of Production Economics, 182*, 113–131. https://doi.org/10.1016/j.ijpe.2016.08.018.

Alexander, K., Birkhofer, G., Gramling, K., Kleinberger, H., Leng, S., Moogimane, D., et al. (2002). *IBM business consulting services focus on retail: Applying auto-ID to improve product availability at the retail shelf*. Auto-ID Center. Business Case IBM-AUTOID-BC-001, Retrieved from http://www.autoidcenter.co.uk/research/IBM-AUTOID-BC-001.pdf.

Amini, M., Otondo, R. F., Janz, B. D., & Pitts, M. G. (2007). Simulation modeling and analysis: A collateral application and exposition of RFID technology. *Production and Operations Management, 16*(5), 586–598.

Arunachalam, D., Kumar, N., & Kawalek, J. P. (2018). Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice. *Transportation Research Part E: Logistics and Transportation Review, 114*, 416–436. https://doi.org/10.1016/j.tre.2017.04.001.

Ashton, K. (2009). That 'internet of things' thing. *RFiD Journal, 22*(7), 97–114.

Atali, A., Lee, H. L., & Ozer, O. (2009). If the inventory manager knew: Value of visibility and RFID under imperfect inventory information. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1351606.

Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. *Computer Networks, 54*(15), 2787–2805.

Bag, S., Wood, L. C., Xu, L., Dhamija, P., & Kayikci, Y. (2020). Big data analytics as an operational excellence approach to enhance sustainable supply chain performance. *Resources, Conservation and Recycling, 153*, 104559. https://doi.org/10.1016/j.resconrec.2019.104559.

Baker, G., Gibbons, R., & Murphy, K. J. (2002). Relational contracts and the theory of the firm. *Quarterly Journal of Economics, 117*(1), 39–84.

Banks, J., Hanny, D., Pachano, M. A., & Thompson, L. G. (2007). *RFID applied*. John Wiley & Sons, Inc.

Barratt, M., & Choi, T. (2007). Mandated RFID and institutional responses: Cases of decentralized business units. *Production and Operations Management, 16*(5), 569–585.

Basole, R. C., & Nowak, M. (2018). Assimilation of tracking technology in the supply chain. *Transportation Research Part E: Logistics and Transportation Review, 114*, 350–370. https://doi.org/10.1016/j.tre.2016.08.003.

Baysan, S., & Ustundag, A. (2013). The cost–benefit models for RFID investments. In *The value of RFID* (pp. 13–22). Springer.

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. *International Journal of Production Research, 57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140.

Beyer, M. A., & Laney, D. (2012). *The importance of 'big data': A definition*. Stamford, CT: Gartner.

Bilal, Z., & Martin, K. (2014). A hierarchical anti-counterfeit mechanism: Securing the supply chain using RFIDs. In *Foundations and practice of security* (pp. 291–305). Springer.

Birkel, H. S., & Hartmann, E. (2019). Impact of IoT challenges and risks for SCM. *Supply Chain Management-an International Journal, 24*(1), 39–61. https://doi.org/10.1108/scm-03-2018-0142.

Biswal, A. K., Jenamani, M., & Kumar, S. K. (2018). Warehouse efficiency improvement using RFID in a humanitarian supply chain: Implications for Indian food security system. *Transportation Research Part E-Logistics and Transportation Review, 109*, 205–224. https://doi.org/10.1016/j.tre.2017.11.010.

Biswal, A. K., Jenamani, M., & Kumar, S. K. (2020). The impact of RFID adoption on donor subsidy through for-profit and not-for-profit newsvendor: Implications for Indian Public Distribution system. *Socio-Economic Planning Sciences, 69*. https://doi.org/10.1016/j.seps.2019.02.002.

Bitkom-RFID-Project-Group. (2005). *An overview for companies seeking to use RFID technology to connect their IT systems directly to therealworld* (pp. 1–50). RFID White Paper Technology, Systems, and Applications. https://doi.org/10.1016/j.seps.2019.02.002.

Bottani, E., & Rizzi, A. (2008). Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain. *International Journal of Production Economics, 112*(2), 548–569.

Brown, K. L., Inman, R. A., & Calloway, J. A. (2001). Measuring the effects of inventory inaccuracy in MRP inventory and delivery performance. *Production Planning & Control, 12*(1), 46–57.

Bryant, R., Katz, R. H., & Lazowska, E. D. (2008). *Big-data computing: Creating revolutionary breakthroughs in commerce*. Computing Research Association. Report, Computing Research Intitiatives for the 21st Century. Retrieved from http://www.cra.org/ccc/docs/init/Big_Data.pdf.

Çakıcı, Ö. E., Groenevelt, H., & Seidmann, A. (2011). Using RFID for the management of pharmaceutical inventory—system optimization and shrinkage control. *Decision Support Systems, 51*(4), 842–852.

Canaday, H. (2017). *Aircraft data ownership debate is ongoing*. AW & ST Inside MRO. Retrieved from https://doi.org/10.19302/j.cnki.1672e0989.2017.05.010 . (Accessed 2 March 2017).

Cannella, S., Dominguez, R., & Framinan, J. M. (2017). Inventory record inaccuracy - The impact of structural complexity and lead time variability. *Omega-International Journal of Management Science, 68*, 123–138. https://doi.org/10.1016/j.omega.2016.06.009.

Cannella, S., Framinana, J. M., Bruccoleri, M., Barbosa-Povoa, A. P., & Relvas, S. (2015). The effect of Inventory Record Inaccuracy in Information Exchange Supply Chains. *European Journal of Operational Research, 243*(1), 120–129. https://doi.org/10.1016/j.ejor.2014.11.021.

CASICloud, T. C. (2019). *The Construction of cloud factory for intelligent manufacturing of automotive stamping die*. Retrieved from. http://www.casicloud.cn/news/121917/detail.html?type=642 (Accessed 20 December 2019).

Chappell, G., Durdan, D., Gilbert, G., Ginsburg, L., Smith, J., & Tobolski, J. (2002). *Auto-ID on delivery: The value of auto-ID technology in the retail supply chain*. Auto-ID Business Case, ACN-Auto-ID-BC-004. http://www. Autoidcenter. Org/Research/ACN-AUTOID-BC-004. Pdf.

Chappell, G., Durdan, D., Gilbert, G., Ginsburg, L., Smith, J., & Tobolski, J. (2003). Auto-ID in the box: The value of auto-ID technology in retail stores. *Auto-ID Center, 2*, 2.
Chen, L. (2014). *Fixing Phantom Stockouts: Optimal Data-Driven Shelf Inspection Policies*. Retrieved from. https://ssrn.com/abstract=2689802. (Accessed 3 August 2014).
Chen, L. (2017). 161 smart life scenarios are on sale,Haier released the world's first set of fully interconnected smart home appliances. *China Appliance, 4*, 30.
Chen, G., Wu, G., Gu, Y., Lu, B., & Wei, Q. (2018). The Challenges for Big Data Driven Research and Applications in the Context of Managerial Decision-Making—paradigm shift and research directions. *Journal of Management Sciences in China, 21*(7), 6–15.
Chen, J., Gusikhin, O., Finkenstaedt, W., & Liu, Y.-N. (2019). Maintenance, Repair, and operations parts inventory management in the era of industry 4.0. *IFAC-PapersOnLine, 52*(13), 171–176. https://doi.org/10.1016/j.ifacol.2019.11.171.
Chen, K., & Zheng, W. (2009). Cloud computing: System instances and current research. *Journal of Software, 20*(5), 1337–1348.
Chen, S., Wang, H., Xie, Y., & Qi, C. (2014). Mean-risk analysis of radio frequency identification technology in supply chain with inventory misplacement: Risk-sharing and coordination. *Omega, 46*, 86–103.
Choi, T. M. (2018). Incorporating social media observations and bounded rationality into fashion quick response supply chains in the big data era. *Transportation Research Part E: Logistics and Transportation Review, 114*, 386–397. https://doi.org/10.1016/j.tre.2016.11.006.
Choi, T. M., Wallace, S. W., & Wang, Y. (2018). Big data analytics in operations management. *Production and Operations Management, 27*(10), 1868–1883. https://doi.org/10.1111/poms.12838.
Condea, C., Thiesse, F., & Fleisch, E. (2012). RFID-enabled shelf replenishment with backroom monitoring in retail stores. *Decision Support Systems, 52*(4), 839–849.
Cui, L., Deng, J., Liu, R., Xu, D., Zhang, Y., & Xu, M. (2020). A stochastic multi-item replenishment and delivery problem with lead-time reduction initiatives and the solving methodologies. *Applied Mathematics and Computation, 374*. https://doi.org/10.1016/j.amc.2020.125055.
Cui, L., Deng, J., Liu, F., Zhang, Y., & Xu, M. (2017). Investigation of RFID investment in a single retailer two-supplier supply chain with random demand to decrease inventory inaccuracy. *Journal of Cleaner Production, 142*, 2028–2044. https://doi.org/10.1016/j.jclepro.2016.11.081.
Cui, L., Deng, J., Wang, L., Zhang, J., & Xu, M. (2018). A Study on the RFID Investment Decision Model for the Revised Joint Replenishment and Delivery Problem. *Chinese Journal of Management Science, 26*(5), 86–97.
Dai, H., Li, J., Yan, N., & Zhou, W. (2016). Bullwhip effect and supply chain costs with low- and high-quality information on inventory shrinkage. *European Journal of Operational Research, 250*(2), 457–469. https://doi.org/10.1016/j.ejor.2015.11.004.
Dai, H., Tan, Y., & Zhou, W. (2018). Collaboration mechanism design with real-time information for supply chains under inventory inaccuracy. *Journal of Industrial Engineering and Engineering Management, 32*(2), 228–239.
Dai, H., & Tseng, M. M. (2012). The impacts of RFID implementation on reducing inventory inaccuracy in a multi-stage supply chain. *International Journal of Production Economics, 139*(2), 634–641.
Dan, B., Mao, Y., & Xu, G. (2012). Inventory coordination for perishable products supply chain based on RFID. *Computcr Integrated Manufacturing Systems, 18*(10), 2280–2286.
DeHoratius, N., & Raman, A. (2008). Inventory record inaccuracy: An empirical analysis. *Management Science, 54*(4), 627–641.
Delen, D., Hardgrave, B. C., & Sharda, R. (2007). RFID for better supply-chain management through enhanced information visibility. *Production and Operations Management, 16*(5), 613–624.
Dutta, A., Lee, H. L., & Whang, S. (2007). RFID and operations management: Technology, value, and incentives. *Production and Operations Management, 16*(5), 646–655.
Dutta, A., & Whang, S. (2007). Radiofrequency identification applications in private and public sector operations: Introduction to the special issue. *Production and Operations Management, 16*(5), 523–524.
Dweekat, A. J., Hwang, G., & Park, J. (2017). A supply chain performance measurement approach using the internet of things. *Industrial Management & Data Systems, 117*(2), 267–286. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=121560127&lang=zh-cn&site=eds-live.
Elecfans. (2016). *Philips Lighting and Xiaomi start a company and both sides are going to make a big move in smart home*. Retrieved from. http://www.elecfans.com/led/ledzhaoming/465172.html. (Accessed 20 August 2019).
Fang, C., Liu, X., Pei, J., Fan, W., & Pardalos, P. M. (2016). Optimal production planning in a hybrid manufacturing and recovering system based on the internet of things with closed loop supply chains. *Operational Research, 16*(3), 543–577. https://doi.org/10.1007/s12351-015-0213-x.
Fan, T., Tao, F., Deng, S., & Li, S. (2015). Impact of RFID technology on supply chain decisions with inventory inaccuracies. *International Journal of Production Economics, 159*, 117–125.
Fan, T. J., Chang, X. Y., Gu, C. H., Yi, J. J., & Deng, S. (2014). Benefits of RFID technology for reducing inventory shrinkage. *International Journal of Production Economics, 147*, 659–665. https://doi.org/10.1016/j.ijpe.2013.05.007.
Fan, W., & Xiao, T. (2011). Cloud manufacturing integration architecture based on federation model. *Computcr Integrated Manufacturing Systems, 17*(3), 469–476.
Feng, Z., Guo, X., Zeng, D., Chen, Y., & Chen, G. (2013). On the research frontiers of business management in the context of Big Data. *Journal of Management Sciences in China, 16*(1), 1–9.
Fleisch, E., & Tellkamp, C. (2005). Inventory inaccuracy and supply chain performance: A simulation study of a retail supply chain. *International Journal of Production Economics, 95*(3), 373–385.
Fosso Wamba, S., Lefebvre, L. A., & Lefebvre, E. (2007). Integrating RFID Technology and EPC Network into a B2B retail supply chain: a step toward intelligent business processes. *Journal of Technology Management & Innovation, 2*(3), 114–124. Retrieved from https://www.jotmi.org/index.php/GT/article/view/art49.
Frankel, F., & Reid, R. (2008). Big data: Distilling meaning from data. *Nature, 455*(7209), 30.
García, A., Chang, Y., Abarca, A., & Oh, C. (2007). RFID enhanced MAS for warehouse management. *International Journal of Logistics, 10*(2), 97–107.
Garrido-Hidalgo, C., Ramirez, F. J., Olivares, T., & Roda-Sanchez, L. (2020). The adoption of Internet of Things in a Circular Supply Chain framework for the recovery of WEEE: The case of Lithium-ion electric vehicle battery packs. *Waste Management, 103*, 32–44. https://doi.org/10.1016/j.wasman.2019.09.045.
Gartner. (2016). *Gartner IT glossary*. Retrieved from. https://www.gartner.com/en/information-technology/glossary/big-data. (Accessed 18 December 2019).
Gaukler, G. M. (2005). *RFID in supply chain management*. Stanford University.
Gaukler, G. M. (2011). Item-level RFID in a retail supply chain with stock-out-based substitution. *Industrial Informatics, IEEE Transactions On, 7*(2), 362–370.
Gaukler, G. M., & Seifert, R. W. (2007). Applications of RFID in supply chain. In H. Jung, F. F. Chen, & B. Jeong (Eds.), *Trends in Supply Chain Design and Management: Technologies and Methodologies*. London: Springer-Verlag London Ltd.
Gill, A. Q., Phennel, N., Lane, D., & Phung, V. L. (2016). IoT-enabled emergency information supply chain architecture for elderly people: The Australian context. *Information Systems, 58*, 75–86. https://doi.org/10.1016/j.is.2016.02.004.
Govindan, K., Cheng, T. C. E., Mishra, N., & Shukla, N. (2018). Big data analytics and application for logistics and supply chain management. *Transportation Research Part E: Logistics and Transportation Review, 114*, 343–349. https://doi.org/10.1016/j.tre.2018.03.011.
Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*(7), 1645–1660.
Guo, W., Tong, K., Shao, H., Wang, L., & Zheng, Q. (2013). Construction of multi-service subject credit evaluation system based on RS and AHP in cloud manufacturing mode of small and medium-sized enterprises. *Computcr Integrated Manufacturing Systems, 19*(9), 2340–2347.
Hall, N. G., & Potts, C. N. (2003). Supply chain scheduling: Batching and delivery. *Operations Research, 51*(4), 566–584.
Hedgepeth, W. O. (2007). *RFID metrics—decision making tools for today's supply chains*. Boca Raton: CRC Press.

Hardgrave, B. C., Aloysius, J. A., & Goyal, S. (2013). RFID-Enabled Visibility and Retail Inventory Record Inaccuracy: Experiments in the Field. *Production and Operations Management, 22*(4), 843–856.
He, D., Song, X., Wang, Q., & Xu, C. (2011). Collaborative design method for complex products based on cloud services. *Computcr Integrated Manufacturing Systems, 17*(3), 533–539.
Heese, H. S. (2007). Inventory record inaccuracy, double marginalization, and RFID adoption. *Production and Operations Management, 16*(5), 542–553.
Hilbert, M., & López, P. (2011). The world's technological capacity to store, communicate, and compute information. *Science, 332*(6025), 60–65.
Holbrook, M. (1994). The nature of customer value: An axiology of services in the consumption experience. In R. T. Rust (Ed.), *Service quality: New directions in theory and practice* (pp. 21–71). https://doi.org/10.4135/9781452229102.
Hou, L., & Zhang, Y. (2014). *Leading high-level win-win cooperation between China and Germany with innovation*. Xinhua Net. Retrieved from http://finance.ifeng.com/a/20141011/13177592_0.shtml.
Huang, B., Li, C., Yin, C., & Zhao, X. (2013). Cloud manufacturing service platform for small-and medium-sized enterprises. *The International Journal of Advanced Manufacturing Technology, 65*(9–12), 1261–1272.
Huang, G., Zhong, X., Long, Y., & Zhang, G. (2011). Manufacturing resource cloud location service platform based on the separation of data cloud and application cloud. *Computcr Integrated Manufacturing Systems, 17*(3), 519–524.
Iacobucci, D., Grayson, K., & Ostrom, A. (1994). Customer satisfaction fables. *Sloan Management Review, 35*(4), 93–96.
ICF. (2020). No title. *Maintenance, Repair and Overhaul*. Retrieved from. https://www.icf.com/work/transportation/aviation/mro. (Accessed 18 January 2020).
Iglehart, D. L., & Morey, R. C. (1972). Inventory systems with imperfect asset information. *Management Science, 18*(8), B388–B394.
Iovweek. (2015). *Futuremove receives tens of millions of angel investment and expands the new map of car networking*. Iovweek website. Retrieved from http://www.iovweek.com/guonei/1358.html.
ITU. (2005). *ITU internet reports 2005: The internet of things* (7th ed.) Retrieved from http://handle.itu.int/11.1002/pub/800eae6f-en.
Jin, F. (2014). Value ecosystem: Value creation mechanism in the era of cloud economy. *China Industrial Economy*, (4), 97–109.
Joshi, Y. V. (2000). *Information visibility and its effect on supply chain dynamics*. Massachusetts Institute of Technology.
Kambil, A., & Brooks, J. D. (2002). *Auto-ID across the value chain: From dramatic potential to greater efficiency and profit*. Accenture White Paper.
Kamble, S. S., Gunasekaran, A., Parekh, H., & Joshi, S. (2019). Modeling the internet of things adoption barriers in food retail supply chains. *Journal of Retailing and Consumer Services, 48*, 154–168. https://doi.org/10.1016/j.jretconser.2019.02.020.
Kang, Y., & Gershwin, S. B. (2005). Information inaccuracy in inventory systems: Stock loss and stockout. *IIE Transactions, 37*(9), 843–859.
Kök, A. G., & Shang, K. H. (2007). Inspection and replenishment policies for systems with inventory record inaccuracy. *Manufacturing & Service Operations Management, 9*(2), 185–205.
Lamba, K., & Singh, S. P. (2017). Big data in operations and supply chain management: Current trends and future perspectives. *Production Planning & Control, 28*(11–12), 877–890. https://doi.org/10.1080/09537287.2017.1336787.
Lavalle, S., Lesser, E., Shockley, R., Hopkins, M. S., & Kruschwitz, N. (2011). Big data, analytics and the path from insights to value. *Mit Sloan Management Review, 52*(2), 21–32.
Lee, H. L., & Tang, C. S. (2018). Socially and environmentally responsible value chain innovations: New operations management research opportunities. *Management Science, 64*(3), 983–996. https://doi.org/10.1287/mnsc.2016.2682.
Lee, Y. M., Cheng, F., & Leung, Y. T. (2004). Exploring the impact of RFID on supply chain dynamics.. In *Winter simulation conference* (pp. 1145–1152).
Lee, Y. M., Cheng, F., & Leung, Y. T. (2009). A quantitative view on how RFID can improve inventory Management in a supply chain. *International Journal of Logistics: Research and Applications, 12*(1), 23–43.
Lee, H. L., & Özer, Ö. (2007). Unlocking the value of RFID. *Production and Operations Management, 16*(1), 40–64.
Lee, H. L., Padmanabhan, V., & Whang, S. (2004). Information distortion in a supply chain: The bullwhip effect. *Management Science, 50*(12_supplement), 1875–1886.
Lefebvre, L. A., Lefebvre, E., Bendavid, Y., Wamba, S. F., & Boeck, H. (2006). *Rfid as an enabler of B-to-Be-commerce and its impact on business processes: A pilot study of a supply chain in the retail industry*. In Proceedings of the 39th Hawaii international conference on system sciences.
Legenvre, H., Henke, M., & Ruile, H. (2020). Making sense of the impact of the internet of things on Purchasing and Supply Management:A tension perspective. *Journal of Purchasing and Supply Management, 26*(1), 100596. https://doi.org/10.1016/j.pursup.2019.100596.
Lei, J. (2017). *Seventy-seven enterprises in Xiaomi ecological chain with a total revenue of 15 billion last year*. Retrieved from. https://tech.qq.com/a/20170518/029678.htm. (Accessed 20 August 2019).
Leung, Y. T., Cheng, F., Lee, Y. M., & Hennessy, J. J. (2007). A tool set for exploring the value of RFID in a supply chain. In *Trends in supply chain design and management* (pp. 49–70). Springer.
Li, M., Wang, Z., & Chan, F. T. S. (2016). A robust inventory routing policy under inventory inaccuracy and replenishment lead-time. *Transportation Research Part E-Logistics and Transportation Review, 91*, 290–305. https://doi.org/10.1016/j.tre.2016.05.001.
Li, X. (2010). The development strategy of Internet of things in Europe, America, Japan, South Korea and China—the global development action of Internet of things. *Radio Frequency Ubiquitous Journal*, (3), 51–55.
Li, Z. (2018). AWE-2018 product trend observation: Artificial intelligence helps household appliances to move towards scene based whole house interconnection by creating more home internet portals. *China Appliance*, (4), 28–29.
Li, H., Ji, Y., Qi, G., Xin, J., & Tang, R. (2010). Connotation, theory and key technology system of integration of manufacturing and service. *Computcr Integrated Manufacturing Systems, 16*(11), 2521–2529.
Li, M., & Wang, Z. (2018). An integrated robust replenishment/production/distribution policy under inventory inaccuracy. *International Journal of Production Research, 56*(12), 4115–4131. https://doi.org/10.1080/00207543.2018.1444808.
Li, R., Liu, Q., & Xu, W. (2012). Cloud manufacturing equipment resource awareness and access adaptation technology. *Computcr Integrated Manufacturing Systems, 18*(7), 1547–1553.
Li, S., Visich, J. K., Khumawala, B. M., & Zhang, C. (2006). Radio frequency identification technology: Applications, technical challenges and strategies. *Sensor Review, 26*(3), 193–202.
Li, J., Wang, A., Tang, C., & Lu, Z. (2012). Distributed collaborative scheduling technology based on dynamic resource capability service. *Computcr Integrated Manufacturing Systems, 18*(7), 1563–1574.
Li, B., Zhang, L., Wang, S., Tao, F., Cao, J., Jiang, X., et al. (2010). Cloud manufacturing:a new service-oriented networked manufacturing model. *Computcr Integrated Manufacturing Systems, 16*(1), 1–7.
Li, B., Zhang, G., & Xin, S. (2012). Cloud manufacturing platform and key technologies for the mold industry supporting collaboration. *Computcr Integrated Manufacturing Systems, 18*(7), 1620–1626.
Li, T., Li, B., & Chai, X. (2012). Hierarchical simulation service description framework for cloud simulation. *Computcr Integrated Manufacturing Systems, 18*(9), 2091–2098.
Luo, Y., Zhang, L., Tao, F., Zhang, X., & Ren, L. (2012). Key technologies of manufacturing capability modeling in cloud manufacturing mode. *Computcr Integrated Manufacturing Systems, 18*(7), 1357–1367.
Lynch, C. (2008). Big data: How do your data grow? *Nature, 455*(7209), 28–29.
Ma, W., Zhu, L., & Wang, W. (2014). Cloud service selection model based on QoS awareness in cloud manufacturing environment. *Computcr Integrated Manufacturing Systems, 20*(5), 1246–1254.
Maass, W., & Varshney, U. (2008). Preface to the focus theme section:'Smart products'. *Electronic Markets, 18*(3), 211–215.
Manavalan, E., & Jayakrishna, K. (2019). A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Computers & Industrial Engineering, 127*, 925–953. https://doi.org/10.1016/j.cie.2018.11.030.

Marr, B. (2015). *Why only one of the 5 Vs of big data really matters*. Blogs-IBM Big Data & Analytics Hub website. Retrieved from https://www.ibmbigdatahub.com/blog/why-only-one-5-vs-big-data-really-matters.

Mattila, A. (1999). Consumers value judgments: How business travelers evaluate luxury-hotel services. *Cornell Hotel and Restaurant Administration Quarterly, 40*(1), 40–46. https://doi.org/10.1016/S0010-8804(99)80013-5.

Mayer-Schönberger, V., & Cukier, K. (2013). *Big data: A revolution that will transform how we live, work, and think*. Boston, MA: Houghton Mifflin Harcourt.

McFarlane, D., Sarma, S., Chirn, J. L., Wong, C., & Ashton, K. (2003). Auto ID systems and intelligent manufacturing control. *Engineering Applications of Artificial Intelligence, 16*(4), 365–376.

Mersereau, A. J. (2013). Information-sensitive replenishment when inventory records are inaccurate. *Production and Operations Management, 22*(4), 792–810.

Metzger, C., Thiesse, F., Gershwin, S., & Fleisch, E. (2013). The impact of false-negative reads on the performance of RFID-based shelf inventory control policies. *Computers & Operations Research, 40*(7), 1864–1873.

MHA. (2017). Bosch: Smart home appliances lead healthy interconnected life. *Modern Home Appliances (MHA)*, (6), 58.

MIIT. (2011). *The 12th Five year development plan of Internet of things*. Retrieved from http://www.miit.gov.cn/.

MIIT. (2015). *Made in China 2025*. Retrieved from http://www.miit.gov.cn/.

Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad Hoc Networks, 10*(7), 1497–1516. https://doi.org/10.1016/j.adhoc.2012.02.016.

Moktadir, M. A., Ali, S. M., Paul, S. K., & Shukla, N. (2019). Barriers to big data analytics in manufacturing supply chains: A case study from Bangladesh. *Computers & Industrial Engineering, 128*, 1063–1075. https://doi.org/10.1016/j.cie.2018.04.013.

Muñuzuri, J., Onieva, L., Cortés, P., & Guadix, J. (2020). Using IoT data and applications to improve port-based intermodal supply chains. *Computers & Industrial Engineering, 139*, 105668. https://doi.org/10.1016/j.cie.2019.01.042.

Musa, A., Gunasekaran, A., & Yusuf, Y. (2014). Supply chain product visibility: Methods, systems and impacts. *Expert Systems with Applications, 41*(1), 176–194.

Ni, W. (2011). *A survey of the policies of internet of things in the United States*. Retrieved from. http://www.istis.sh.cn/list/list.aspx?id=7194. (Accessed 18 December 2019).

Nooraie, S. V., & Parast, M. M. (2015). A multi-objective approach to supply chain risk management: Integrating visibility with supply and demand risk. *International Journal of Production Economics, 161*, 192–200.

Ofweek. (2017). *Not only mobile phones, but also Xiaomi's ecological chain company*. Retrieved from. https://ee.ofweek.com/2017-07/ART-8320315-8460-30158345.html. (Accessed 20 August 2019).

Park, S., Hong, K., & Lee, C. (2015). Optimal maintenance operations using a RFID-based monitoring system. *International Journal of Industrial Engineering-Theory Applications and Practice, 22*(1), 117–125.

Piramuthu, S., Wochner, S., & Grunow, M. (2014). Should retail stores also RFID-tag 'cheap'items? *European Journal of Operational Research, 233*(1), 281–291.

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard Business Review, 92*(11), 64–88.

Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard Business Review, 93*(10), 96–114.

Presser, M., & Gluhak, A. (2009). *The internet of things: Connecting the real world with the digital world. EURESCOM Mess@ Ge–the Magazine for telecom insiders*. EURESCOM Mess@ Ge–the Magazine for telecom insiders.

Qu, T., Thurer, M., Wang, J., Wang, Z., Fu, H., Li, C., et al. (2017). System dynamics analysis for an Internet-of-Things-enabled production logistics system. *International Journal of Production Research, 55*(9), 2622–2649. https://doi.org/10.1080/00207543.2016.1173738.

Ranky, P. (2012). *An introduction to RFID, radio frequency identification methods & applications. a DVD Video and browser readable 3D multimedia eBook Combo* (UPC 632568001511).

Rekik, Y. (2011). Inventory inaccuracies in the wholesale supply chain. *International Journal of Production Economics, 133*(1), 172–181.

Rekik, Y., Sahin, E., & Dallery, Y. (2008). Analysis of the impact of the RFID technology on reducing product misplacement errors at retail stores. *International Journal of Production Economics, 112*(1), 264–278.

Rekik, Y., Sahin, E., & Dallery, Y. (2009). Inventory inaccuracy in retail stores due to theft: An analysis of the benefits of RFID. *International Journal of Production Economics, 118*(1), 189–198.

Ren, L., Lin, Z., Tao, F., & Luo, Y. (2011). Research on cloud manufacturing resource virtualization. *Computcr Integrated Manufacturing Systems, 17*(3), 511–518.

Rezaei, M., Shirazi, M. A., & Karimi, B. (2017). IoT-based framework for performance measurement A real-time supply chain decision alignment. *Industrial Management & Data Systems, 117*(4), 688–712. https://doi.org/10.1108/imds-08-2016-0331.

Sahin, E., Buzacott, J., & Dallery, Y. (2008). Analysis of a newsvendor which has errors in inventory data records. *European Journal of Operational Research, 188*(2), 370–389.

Schoenherr, T., & Speier-Pero, C. (2015). Data science, predictive analytics, and big data in supply chain management: Current state and future potential. *Journal of Business Logistics, 36*(1), 120–132.

Sendler, U., Deng, M., & Li, X. (2014). In *Industrie 4.0–Beherrschung der industriellen Komplexität mit SysLM (Systems Lifecycle Management)* (E.1 Ed.). Beijing: China Machine Press.

Shen, B., Qi, D., & Fan, L. (2011). Collaborative engineering support technology for manufacturing enterprises based on Service-Oriented architecture. *Computcr Integrated Manufacturing Systems, 17*(4), 876–881.

Sijie. (2016). *Xiaomi and Philips Lighting set up a joint venture to do intelligent lighting, what about Yeenlight?* Retrieved from. https://36kr.com/p/5055921. (Accessed 20 July 2019).

Sina. (2014). *Midea and Alibaba pushes IOT air conditioning: eight modes to enhance the experience*. Retrieved from. http://tech.sina.com.cn/e/2014-03-17/22149248431.shtml. (Accessed 18 December 2019).

Singh, A., Shukla, N., & Mishra, N. (2018). Social media data analytics to improve supply chain management in food industries. *Transportation Research Part E: Logistics and Transportation Review, 114*, 398–415. https://doi.org/10.1016/j.tre.2017.05.008.

Tao, F., Fan, T., Lai, K. K., & Li, L. (2017). Impact of RFID technology on inventory control policy. *Journal of the Operational Research Society, 68*(2), 207–220. https://doi.org/10.1057/s41274-016-0030-5.

Tao, F., Fan, T., Wang, Y. Y., & Lai, K. K. (2019). Joint pricing and inventory strategies in a supply chain subject to inventory inaccuracy. *International Journal of Production Research, 57*(9), 2695–2714. https://doi.org/10.1080/00207543.2019.1579933.

Tao, F., Lai, K., Wang, Y. Y., & Fan, T. (2020). Determinant on RFID technology investment for dominant retailer subject to inventory misplacement. *International Transactions in Operational Research, 27*(2), 1058–1079.

Tellkamp, C. (2003). *The auto-ID calculator: An overview. Auto-ID center white paper*.

Tellkamp, C. (2006). *The impact of auto-ID technology on process performance: RFID in the FMCG supply chain. Ph.D.Thesis*. The University of St. Gallen.

Thiesse, F., & Buckel, T. (2015). A comparison of RFID-based shelf replenishment policies in retail stores under suboptimal read rates. *International Journal of Production Economics, 159*, 126–136.

Thonemann, U. W. (2002). Improving supply-chain performance by sharing advance demand information. *European Journal of Operational Research, 142*(1), 81–107.

Tien, J. M. (2012). The next industrial revolution: Integrated services and goods. *Journal of Systems Science and Systems Engineering, 21*(3), 257–296.

Tien, J. M. (2015). Internet of connected ServGoods: Considerations, consequences and concerns. *Journal of Systems Science and Systems Engineering, 24*(2), 130–167.

Tu, M., Lim, M. K., & Yang, M.-F. (2018). IoT-based production logistics and supply chain system - Part 1 Modeling IoT-based manufacturing IoT supply chain. *Industrial Management & Data Systems, 118*, 65–95. https://doi.org/10.1108/IMDS-11-2016-0503.

Vance, A. (2010). *Start-up goes after big data with hadoop helper. New York Times Blog*.

Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J., Dubey, R., & Childe, S. J. (2017). Big data analytics and firm performance: Effects of dynamic capabilities. *Journal of Business Research, 70*, 356–365. https://doi.org/10.1016/j.jbusres.2016.08.009.

Wang, F., Fang, X., Chen, X., & Li, X. (2016). Impact of inventory inaccuracies on products with inventory-dependent demand. *International Journal of Production Economics, 177*, 118–130. https://doi.org/10.1016/j.ijpe.2016.04.019.

Wang, G., Gunasekaran, A., Ngai, E. W. T., & T., Papadopoulos (2016). Big data analytics in logistics and supply chain management: Certain investigations for research and applications. *International Journal of Production Economics, 176*, 98–110. https://doi.org/10.1016/J.IJPE.2016.03.014.

Wang, S. J., Liu, S. F., & Wang, W. L. (2008). The simulated impact of RFID-enabled supply chain on pull-based inventory replenishment in TFT-LCD industry. *International Journal of Production Economics, 112*(2), 570–586.

Wang, T., Hu, B., Chang, S., & Ding, L. (2018). Inventory inaccuracies and radio frequency identification technology: Risk analysis and coordination. *Computers & Industrial Engineering, 125*, 9–22. https://doi.org/10.1016/j.cie.2018.08.003.

Wang, X. V., & Xu, X. W. (2013). An interoperable solution for Cloud manufacturing. *Robotics and Computer-Integrated Manufacturing, 29*(4), 232–247.

Wang, Z., Yang, C., Zhang, X., Chen, L., & Zhao, M. (2012). Cloud capability service for production and processing in cloud manufacturing environment. *Computcr Integrated Manufacturing Systems, 18*(7), 1453–1460.

Whitaker, J., Mithas, S., & Krishnan, M. S. (2009). A field study of RFID deployment and return expectations. *Production and Operations Management, 16*(5), 599–612.

White, T. (2012). *Hadoop: The definitive guide*. O'Reilly Media, Inc.

Wu, H. (2013a). Internet and big data. *Computer CD Software and Application, 9*, 64–65.

Wu, H. (2013b). Opportunities and challenges in the era of big data. *China Information Security, 3*, 9–10.

Wu, N., & Wang, H. (2014). *The development of Management Science in the context of big data*. In (pp. 22–28). Systems engineering theory and application—proceedings of the fifth academic annual meeting of guizhou system engineering society.

Xi, J. (2014). China and Germany work together to benefit China, Europe and the world. *Frankfurter Allgemeine Zeitung of Germany*. Retrieved from http://www.China-Un.Ch/Eng/Xwdt/T1141878.Htm.

Xu, X. (2012). From cloud computing to cloud manufacturing. *Robotics and Computer-Integrated Manufacturing, 28*(1), 75–86.

Xu, J. (2014). *Listed companies have set foot in the Internet of vehicles*. China Securities Journal. Retrieved from http://www.cs.com.cn/ssgs/gsxw/201412/t20141205_4581514.html.

Xu, Z., Feng, Z., Guo, X., Zeng, D., & Chen, G. (2014). Frontier topics in management and decision-making driven by big data. *Management World, 254*(11), 158–163.

Yamazaki, R., & Tanaka, S. (2015). *GE's destructive power: Three trumps to subvert manufacturing*. Nikkei Business on website. Retrieved from http://www.china-nengyuan.com/news/71877.html. (Accessed 18 December 2019).

Yao, X., Lian, Z., Li, Y., Jin, H., Xu, C., Tan, W., et al. (2012). Cloud manufacturing service architecture and integrated development environment. *Chinese Journal of Management Science, 18*(10), 2312–2322.

Yao, X., Lian, Z., Yang, Y., Zhang, Y., & Jin, H. (2014). Intelligent Manufacturing – a new mode of man machine and object collaborative manufacturing facing the future Internet. *Computcr Integrated Manufacturing Systems, 20*(6), 1490–1498.

Yin, C., Huang, B., Fei, L., Wen, L., Wang, C., Li, X., et al. (2011). Common key technology system of cloud manufacturing service platform for small and medium-sized enterprises. *Computcr Integrated Manufacturing Systems, 17*(3), 495–503.

Yin, S., Yin, C., Liu, F., & Li, X. (2011). Service mode and semantic description of outsourcing resource integration in cloud manufacturing environment. *Computcr Integrated Manufacturing Systems, 17*(3), 525–532.

Yin, C., Zhang, Y., & Zhong, T. (2012). Cloud manufacturing service resource combination optimization model for new product development. *Computcr Integrated Manufacturing Systems, 18*(7), 1368–1378.

Zadeh, A. H., Sharda, R., & Kasiri, N. (2016). Inventory record inaccuracy due to theft in production-inventory systems. *International Journal of Advanced Manufacturing Technology, 83*(1–4), 623–631. https://doi.org/10.1007/s00170-015-7433-3.

Zhan, D., Cheng, Z., Zhao, X., Nie, L., & Xu, X. (2012). Manufacturing services and its maturity model. *Computcr Integrated Manufacturing Systems, 18*(7), 1584–1594.

Zhang, L., Fan, T., & Liu, B. (2017). Equilibrium strategies of RFID adoption in the supply chain with inventory misplacement. *Systems Engineering-Theory & Practice, 37*(12), 3079–3087.

Zhang, L., Hu, J., Fan, T., & Yang, H. (2012). Deterioration item manufacturers decision-making on RFID technology investment based on critical price. *Chinese Journal of Management Science, 20*(2), 144–151.

Zhang, L., Luo, Y., Fan, W., Tao, F., & Ren, L. (2011). Analysis of cloud manufacturing and related advanced manufacturing models. *Computcr Integrated Manufacturing Systems, 17*(3), 458–468.

Zhang, L., Luo, Y., Tao, F., Li, B., Ren, L., Zhang, X., et al. (2014). Cloud manufacturing: A new manufacturing paradigm. *Enterprise Information Systems, 8*(2), 167–187.

Zhang, L. H., Li, T., & Fan, T. J. (2018b). Radio-frequency identification (RFID) adoption with inventory misplacement under retail competition. *European Journal of Operational Research, 270*(3), 1028–1043. https://doi.org/10.1016/j.ejor.2018.04.038.

Zhang, L. H., & Yang, H. (2019). Incentives for RFID adoption with imperfect read rates: Wholesale price premium versus cost sharing. *Journal of the Operational Research Society, 70*(8), 1440–1456. https://doi.org/10.1080/01605682.2018.1506252.

Zhang, Y., & Wang, Z. (2019). Optimal RFID Deployment in a Multiple-Stage Production System Under Inventory Inaccuracy and Robust Control Policy. *IEEE Transactions on Industrial Informatics, 15*(6), 3230–3242. https://doi.org/10.1109/tii.2018.2878638.

Zhang, Y., Zhang, G., Yang, T., Wang, J., & Sun, S. (2014). Service encapsulation and cloud access of cloud manufacturing and processing equipment. *Computcr Integrated Manufacturing Systems, 20*(8), 2029–2037.

Zhang, Y., Zhao, L., & Qian, C. (2017). Modeling of an IoT-enabled supply chain for perishable food with two-echelon supply hubs. *Industrial Management & Data Systems, 117*(9), 1890–1905. https://doi.org/10.1108/imds-10-2016-0456.

Zhao, D., Du, Q., Xu, C., & Yuan, B. (2015). Manufacturing resources transshipment based on internet of things platform. *Systems Engineering, 33*(1), 88–93.

Zhao, D., & Wu, C. (2015). *Striving for the first-mover advantage of the internet of things*. People's Daily.

Zhou, W. (2009). RFID and item-level information visibility. *European Journal of Operational Research, 198*(1), 252–258.

Zhou, L., Chong, A. Y. L., & Ngai, E. W. T. (2015). Supply chain management in the era of the internet of things. *International Journal of Production Economics, 159*, 1–3. https://doi.org/10.1016/j.ijpe.2014.11.014.

Zhou, W., & Piramuthu, S. (2013). Remanufacturing with RFID item-level information: Optimization, waste reduction and quality improvement. *International Journal of Production Economics, 145*(2), 647–657.

Zinkhan, G. M. (2003). A look to the future of JAMS: Three years out, thirty years out. *Journal of the Academy of Marketing Science, 31*(3), 225–228.

Zipkin, P. (2006). OM forum-the best things in life were free: On the technology of transactions. *Manufacturing & Service Operations Management, 8*(4), 321–329.